NOTICE

All drawings located at the end of the document.

IF150

Department of Energy

ROCKY FLATS OFFICE
P.O. BOX 928
GOLDEN, COLORADO 80402-0928

FEB 0 2 1994

94-DOE-01495

Mr. Martin Hestmark
U. S. Environmental Protection Agency, Region VIII
ATTN: Rocky Flats Project Manager, 8HWM-FF
999 18th Street, Suite 500
Denver, Colorado 80202-2405

Mr. Gary Baughman
Hazardous Waste Facilities Unit Leader
Colorado Department of Health
4300 Cherry Creek Drive South
Denver, Colorado 80222-1530

Gentlemen:

We are transmitting copies of the draft document entitled "Technical Memorandum (TM) No. 1, Operable Unit No. 2 Subsurface Interim Measure/Interim Remedial Action, Soil Vapor Extraction (SVE) Pilot Test" dated January 1994. The purpose of this TM is to evaluate the impact of the Non-Aqueous Phase Liquid on the SVE pilot equipment modifications and test objectives.

If you have any questions, please contact Scott Grace at 966-7199.

Sincerely,

Richard J. Schassburger

Richard J. Schassburger
Acting Deputy Assistant Manager
Environmental Restoration

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FEB 03 1994
HAZARDOUS MATERIALS
AND WASTE MANAGEMENT

RECEIVED
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Enclosure

cc w/Enclosure:
A. Rampertaap, EM-453

cc w/o Enclosure:
E. Dille, ER, AEI
M. Klein, EG&G
P. Laurin, EG&G
S. Stiger, EG&G
J. Schieffelin, CDH
B. Fraser, EPA

1F150

PRELIMINARY DRAFT
TECHNICAL MEMORANDUM NO. 2
OU-2 SUBSURFACE IM/IRA
SOIL VAPOR EXTRACTION PILOT TEST
OFFGAS TREATMENT ALTERNATIVES EVALUATION

Rocky Flats Plant

(Operable Unit No. 2)

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden, Colorado

March 1994

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APPROVED BY:

Project Manager
Environmental Restoration

Date

APPROVED BY:

Department/Group Manager
Environmental Restoration

Date

APPROVED BY:

Quality Assurance Program Manager
Environmental Restoration

Date

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LIST OF ACRONYMS

APEN	Air Pollution Emission Notice
BGS	below ground surface
BH	borehole
BTU	British Thermal Unit
CDH	Colorado Department of Health
CFR	Code of Federal Regulations
CHC	chlorinated hydrocarbon
CMS/FS	Corrective Measure Study/Feasibility Study
DCA	dichloroethane
DCE	dichloroethene
DOE/RFO	Department of Energy/Rocky Flats Office
DRE	destruction removal efficiency
EPA	Environmental Protection Agency
GAC	granular activated carbon
HAP	hazardous air pollutant
HEPA	high efficiency particulate air
Hz	hertz
IHSS	Individual Hazardous Substance Site
IM/IRAP	Interim Measure/Interim Remedial Action Plan
kg	kilogram
kW	kilowatt
MACT	Maximum Achievable Control Technology
NAPL	non-aqueous phase liquid
NSR	New Source Review
OU-2	Operable Unit No. 2
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PID	photoionization detector
RCRA	Resource Conservation and Recovery Act
RFA	Rocky Flats Alluvium
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFP	Rocky Flats Plant
SPSH	six-phase electrical soil heating
SVE	Soil Vapor Extraction

SVOC	semi-volatile organic compound
TCA	trichloroethane
TCE	trichloroethene
TM	Technical Memorandum
tpy	tons per year
TSD	treatment storage disposal
UHSV	upper hydrostratigraphic unit
UTL	Upper Threshold Limit
UV	ultraviolet
V	volt
VOC	Volatile Organic Compound
°F	Fahrenheit
μg	microgram

1.0 INTRODUCTION

The objective of technical memorandum No. 2 is to identify, evaluate, and select an appropriate offgas treatment technology for removal of VOCs from extracted soil gas. The primary criteria for this selection is that it meets performance standards for applications planned at OU-2, Pilot Test Sites No. 1 and No. 2.

The review addresses the existing SVE pilot unit and the additional system design requirements for thermally enhanced removal of organics using Six Phase Soil Heating (SPSH). Nonaqueous phase liquids identified in the subsurface soils from previous drilling programs have the potential to exceed the existing capacity of the offgas treatment system using Granular Activated Carbon (GAC).

An important secondary criteria is that the design meets the potential requirements of future offgas treatment applications for additional SVE programs at the Rocky Flats Plant (RFP) site. This requires the treatment system be portable and able to efficiently treat a broad range of contaminant concentrations. The scope of identification, evaluation and selection of the treatment system is limited to technologies which can be retrofitted to the existing SVE pilot unit and operate in a self-contained manner.

1.1 PROJECT OVERVIEW

In September 1992, the Department of Energy/Rocky Flats Office (DOE/RFO) released a final Subsurface Interim Measure/Interim Remedial Action Plan (IM/IRAP) to investigate the removal of volatile organic compound (VOC) contamination from three areas within Operable Unit 2 (OU-2). Specifically, the SVE technology would be pilot tested within, or adjacent to, suspected VOC source areas in the 903 Pad, Mound and East Trenches. The Final Pilot Test Plan for the SVE technology was submitted to Colorado Department of

Health (CDH) and Environmental Protection Agency (EPA) in January 1993, for Pilot Test No. 1 at the East Trenches (DOE 1993c).

In 1993, a pilot SVE unit using GAC for offgas treatment was fabricated off site. The unit was installed at Trench T-3, Individual Hazardous Substance Site (IHSS) 110 within OU-2. Pilot Test No. 1 is currently in progress. Pilot Test No. 2, scheduled for Spring 1995, will incorporate SPSH with the SVE technology.

In support of the pilot tests, this document is prepared to identify and evaluate the requirements for an alternative offgas treatment system. This system would be used with the existing SVE pilot unit and the SPSH system. Technical Memorandum (TM) No. 2 will identify and recommend an alternative offgas treatment system to be designed and purchased to support the SVE pilot tests. The potential sitewide application of the SVE system and alternative offgas treatment will also be evaluated.

1.2 MEMORANDUM OBJECTIVES

The purpose of this technical memorandum is to identify, evaluate, and recommend an offgas treatment system to support the SPSH and SVE technology pilot tests. The memorandum objectives include the following:

- Review and summarize the objectives for the IM/IRAP, Pilot Test No. 1, Pilot Test No. 2 and any additional pilot tests.
- Review and summarize the nature and extent of contamination at the pilot test site.
- Define the air emission standards or limits that the offgas treatment system would be required to achieve.

- Identify the design criteria for an offgas treatment system for the SVE and six-phase heating technologies.

- Evaluate various offgas treatment systems with respect to effectiveness, implementability and cost.

- Identify by-products from the SVE six phase and offgas treatment systems.

- Develop alternatives for offgas treatment.

- Identify required modifications to the existing SVE pilot system.

- Identify and recommend an offgas treatment alternative to support the pilot tests.

1.3 ORGANIZATION

TM No. 2 is organized into nine sections including references and appendixes:

- Section 1.0, Introduction, presents the project overview, the memorandum objectives and organization.

- Section 2.0, Approach and Pilot Test Objectives and Scope, presents the approach for developing and evaluating the offgas treatment alternatives, IM/IRAP objectives and the pilot test objectives.

- Section 3.0, Pilot Test Site Subsurface Conditions, presents the nature and extent of contamination at the pilot test site, soil characteristics, and soil gas survey results.

- Section 4.0, Basis of Design for Offgas Treatment System, presents the design and operating criteria for the SVE system, design criteria, and air emission limits for an offgas treatment system.

- Section 5.0, Technology Identification and Screening, presents offgas treatment technologies and an evaluation or screening of these technologies with respect to effectiveness, implementability and cost.

- Section 6.0, Development and Evaluation of Alternatives, presents a summary of the design basis and alternatives for offgas treatment. This section will also present costs associated with these alternatives.

- Section 7.0, Summary and Recommendations, presents a brief summary of the report and recommends an offgas treatment alternative.

- Section 8.0, contains the references.

2.0 APPROACH AND PILOT TEST OBJECTIVES AND SCOPE

The following sections identify the approach for developing and evaluating the offgas treatment alternatives and also presents the objectives of the scheduled pilot tests.

2.1 OFFGAS TREATMENT EVALUATION APPROACH

In order to evaluate potential alternatives for the offgas treatment system, design criteria including site subsurface conditions, air and condensate emission requirements, waste restrictions, as well as comparison to the existing offgas treatment systems capabilities will be established. Available offgas treatment technologies will be identified, described, and evaluated with respect to the design criteria. The selected technologies will be developed into offgas treatment alternatives which, in turn, will be screened. Last, the selected treatment alternative will be summarized and recommended.

The basis of design for the offgas treatment system will be partly comprised of site subsurface conditions identified by the Phase II RCRA Facility Investigation/Remedial Investigation (RFI/RI) and SVE investigations. In addition, the design criteria will be based on air emission requirements mandated by the CDH, condensate emission requirements, and waste disposal restrictions. Other criteria to which the offgas treatment system must conform to will include portability, ease of retrofit to the existing SVE pilot unit, utility requirements, and time requirements (extraction rate). Last, the offgas treatment system design will meet or exceed the existing offgas unit capabilities.

A series of offgas treatment technologies will be identified as potential replacement systems. These technologies will undergo a feasibility study including a description of the technology and an evaluation with respect to the design criteria. This evaluation will involve a review of each technology including advantages and disadvantages, and identification of selected technologies for further design development.

Developing conceptual design alternatives from the applicable offgas treatment technologies will include conformance to design criteria, consideration of capital, installation, and operating costs, as well as operation and maintenance requirements. Additionally, modifications to the inlet stream or further treatment of the outlet stream will be investigated for each design alternative. An evaluation and comparison of the potential alternatives will be performed followed by a recommendation of the preferred alternative.

2.2 IM/IRAP OBJECTIVES

The IM/IRAP objective was to investigate the removal of VOC contamination in suspected subsurface areas at OU-2 using SVE technology. The IM/IRAP identified three locations to test SVE technology.

2.3 PILOT TEST NO. 1 OBJECTIVES

Pilot Test No. 1 of the SVE technology was designed to select a contaminated site based on soil gas survey data. The following are overall objectives of the pilot study:

- Assess the SVE technology for removal of VOCs in the Rocky Flats Alluvium (RFA) formation.
- Assess the SVE technology for removal of VOCs in sandstone with groundwater extraction.
- Assess active versus passive air injection.
- Incorporate information into the Corrective Measure Study/Feasibility Study (CMS/FS).

- Minimize adverse effects to environment during the pilot test.

2.4 PILOT TEST NO. 2 OBJECTIVES

Pilot Test No. 2 will use the SPSH to test thermally enhanced removal of organics from the subsurface soil with the SVE technology. By increasing the temperature of the soil and contaminant, the contaminant's vapor pressure is increased, increasing its removal rate. Soil heating can also create an in situ source of steam to strip VOCs from soils. Removal of soil moisture (as steam) also tends to increase the flow permeability of soils, which can further increase the rate of contaminant removal by simultaneous venting.

2.5 ADDITIONAL PILOT TEST OBJECTIVES

(LATER)

3.0 PILOT TEST SITE SUBSURFACE CONDITIONS

The location for Pilot Tests No. 1 and No. 2 is Trench T-3 as shown on Figure 3.1-1, which is located north of Central Avenue, east of the inner fence, and south of South Walnut Creek. Trench T-3 was used from 1954 to 1963 for burial of sanitary sewage sludge contaminated with depleted uranium and plutonium in addition to flattened drums contaminated with depleted uranium. The nature and extent of contamination within subsurface soils and soil gas in the vicinity of Trench T-3 are discussed below.

3.1 SUBSURFACE SOILS

Three source boreholes, four plume characterization monitoring wells, and six SVE locations were drilled and sampled during Phase I, Phase II, and SVE investigations to characterize the vertical extent of contamination in Trench T-3 (10191, 02991, 12191, 21693, 22493, BH3987, BH4087, 24093, 24193, 24493, 24593, 24693, 24793, and 25093). The subsurface soil sample results from these boreholes and wells were used in the statistical detection frequency calculations (Table 3.1-1 and Figures 3.1-2 and 3.1-3).

VOCs

Seventeen VOCs were detected in subsurface soil samples collected within Trench T-3 (IHSS 110), as shown on Table 3.1-1. Some of these are suspected laboratory and field contaminants (see the OU-2 Phase II RFI/RI report [DOE 1993a] for further discussion); (acetone, toluene, methylene chloride, and 2-butanone). Free product was observed in borehole 10191 at a depth of 4.2 feet during drilling. Source borehole 10191 exhibited elevated levels of 1,1,1-trichloroethane (TCA), carbon tetrachloride (CCl_4), chloroform ($CHCl_3$), tetrachloroethene (PCE), and trichloroethene (TCE) in the samples collected above the initial water at the time of drilling. In general, the concentrations of the chlorinated hydrocarbons (CHCs) decreased with depth in the vadose zone in source borehole 10191.

Below the water table, concentrations increased again, but to levels significantly lower than those seen in the vadose zone.

Semi-volatile Organic Compounds (SVOCs)

Ten SVOCs were detected in subsurface soil samples collected within Trench T-3, as shown on Table 3.1-1.

Pesticides/PCBs

Aroclor-1254, a polychlorinated biphenyl (PCB), was detected at an estimated concentration of 6,900D μg/kg in borehole 10191 from 1 out of 21 samples analyzed, taken at the depth of 4.2 to 8 feet, as shown on Table 3.1-1.

Radionuclides

Eight radionuclides detected at activities above the background UTLs are presented in Table 3.1-1. Elevated levels of radionuclides are concentrated in the 4.2- to 8-foot interval of borehole 10191 and generally decrease with depth, indicating the source of radionuclides to be within Trench T-3. Trench T-3 is estimated to be between 5 and 10 feet deep.

Summary

The subsurface soil analytical data collected from Trench T-3 indicate that it is a source of VOC contamination (1,1,1-TCA, CCl_4, $CHCl_3$, PCE, TCE, and 1,2-DCA) to the subsurface soil and potentially to upper hydrostratigraphic unit (UHSU) groundwater. The concentrations of CHCs decrease with depth down to the water table. There is minor contamination by polyaromatic hydrocarbons (PAHs) and other SVOCs. Elevated activities of Am-241, Pu-239, Pu-239/240, U-233,234, U-235, and U-238 are also present in Trench T-3.

3.2 SOIL GAS

Two soil gas surveys have been performed around Trench T-3 (IHSS 110). Both a shallow and a deeper survey have been carried out. The findings of the soil gas surveys are summarized below. The shallow (near surface less than a depth of five feet) soil gas survey analyses included the following VOCs:

- 1,1-dichloroethene (DCE)
- trans-1,2-dichloroethene (trans-1,2-DCE)
- cis-1,2-dichloroethene (cis-1,2-DCE)
- 1,1-dichloroethane (DCA)
- 1,2-DCA
- CCl_4
- PCE
- TCE
- Vinyl chloride
- Total VOCs

1,1-DCE, trans-1,2-DCE, cis-1,2-DCE, and 1,2-DCA were not detected in the soil vapor. 1,1-DCA was detected in 16 of 35 sampling locations and concentrations ranged from 40 to 1,900 μg/l. CCl_4 was detected in 18 of the 35 sampling locations with concentrations ranging from 0.36 to 111 μg/l. TCE was detected in 14 of the 35 sampling locations with concentrations ranging from 1.2 to 21 μg/l. PCE was detected in 22 of the 35 sampling locations with concentrations ranging from 0.11 to 410 μg/l. Vinyl chloride was detected in two sampling locations at concentrations less than 23 μg/l.

Review of the spatial distribution of the soil gas data in Trench T-3 indicates that CCl_4 may be found only in the west end of the trench (west of borehole 10191). The PCE soil gas plume is located in the west central part of Trench T-3 (located east of borehole 10191 and around the SVE wells and boreholes). The TCE soil gas plume is similar in location to the PCE plume. Two elevated total VOC concentration areas are observed in and around Trench T-3. One is located in the west central part of Trench T-3 (around the SVE wells and boreholes) and the second is located on the western end of Trench T-3 (west of borehole 10191).

The deeper soil gas survey (two surveys from depths of 5 and 10 feet) analytes are shown in Table 3.2-1 and include:

- 1,1-DCA
- CCl_4
- PCE
- TCE
- Total VOCs

Based on the evaluation of the soil gas obtained from the 5-foot sampling intervals, total VOCs appear to be concentrated on the western part of Trench T-3 (around borehole 10191). The CCl_4 soil vapor plume is located west of Trench T-3 boundary, while 1,1-DCA, PCE, and TCE are located at the western end of Trench T-3.

Review of the soil gas data obtained from a depth of 10 feet indicates that total VOCs, CCl_4, and PCE were observed at higher concentrations than at the 5-foot depth. 1,1-DCA was not detected in the 10-foot sample and TCE was detected at relatively low concentrations.

3.3 NONAQUEOUS PHASE LIQUID (NAPL)

A free phase NAPL, dark-brown in color, was observed in borehole 10191 (Phase II RFI/RI program) at a depth of approximately 4 feet and a residual NAPL was identified at approximately 6.5 to 7 feet during drilling operations. Borehole 10191 was drilled to a depth of 54 feet in three days. Analytical results obtained at this depth indicated the NAPL to contain the following chemicals: 1,1,1-TCA (13,000 μg/kg or ppb), CCl_4 (28,000 μg/kg), $CHCl_3$ (8,800 μg/kg), PCE (1,300,000 μg/kg), and TCE (120,000 μg/kg).

Based on the physical properties that control the migration of NAPLs, their free phase existence in or beneath Trench T-3 is unclear. It is possible that the free phase NAPL observed in borehole 10191 migrated vertically during the Phase II drilling operations or could be still trapped in Trench T-3.

At borehole 24793 in the SVE Pilot Test program, two VOC samples were collected because elevated organic readings were observed in the field by the photoionization detector (PID) and the discolored soil was observed in the borehole from the 7.7- to 8-foot sampling interval. The 7.7- to 8-foot core samples were described in the field to be a residual of a NAPL that discolored the soil. No free phase liquids were observed for these samples. Elevated PCE (1,090,000 μg/kg) and TCE (8,100 μg/kg) were detected in these samples. Upon encountering the NAPL in borehole 24793, drilling was stopped and the borehole was abandoned in accordance with standard operating procedure (SOP) GT.5, Plugging and Abandonment of Boreholes to prevent further contaminant migration.

3.4 SOIL CHARACTERISTICS

The surface soils at OU-2 are predominantly deep, well-drained loams, clay loams and very cobbly sandy loams with slow permeability. The Rocky Flats alluvium with the OU-2 area consist predominantly of beds and lenses of poorly to moderately sorted gravels and sands.

A few lenses of clay and silt also occur. Results of geotechnical analyses are summarized in Table 3.4-1.

TABLE 3.1-1

ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Volatile Organic Compounds (µg/kg)						
Acetone	NA	57	30	52.6%	1085 - 96,000	7,511
Toluene	NA	58	33	56.9%	5J - 7,600	465
Methylene chloride	NA	58	15	25.9%	45 - 20	8.8
2-Butanone	NA	58	9	15.5%	40J - 140	67.1
1,1,1-Trichloroethane	NA	58	9	15.5%	6 - 27,000	8047
Carbon tetrachloride	NA	58	19	32.8%	3J - 700,000	62,964
Chloroform	NA	58	17	29.3%	1J - 8800	536
Tetrachloroethene	NA	58	28	48.3%	1J - 13,000,000	1,037,989
Trichloroethene	NA	58	7	12.1%	1J - 120,000	18,303
1,1-Dichloroethene	NA	58	1	1.7%	9	9
1,2-Dichloroethane	NA	58	4	6.9%	6J - 15J	11.7
1,2-Dichloroethene	NA	58	1	1.7%	1J	1
2-Propenoic acid, 2-methyl	NA	1	1	100.0%	6J	6
Ethylbenzene	NA	58	1	1.7%	2J	2
Methyl methacrylate	NA	1	1	100.0%	6J	6
Styrene	NA	58	1	1.7%	2BJ	2
Total xylenes	NA	58	1	1.7%	7BJ	7

TABLE 3.1-1 (Continued)

ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Semivolatile Organic Compounds (µg/kg)						
Bis(2-ethylhexyl)phthalate	NA	21	20	95.2%	51J - 5500	503.8
Di-n-butyl phthalate	NA	21	1	4.8%	1300J	1300
Phenanthrene	NA	21	1	4.8%	2700J	2700
N-nitrosodiphenylamine	NA	21	1	4.8%	33J	33
2-Methylphenol	NA	21	1	4.8%	450	450
4-Methylphenol	NA	21	1	4.8%	2900	2900
Hexachlorobutadiene	NA	21	1	4.8%	170J	170
Hexachloroethane	NA	21	2	9.5%	370-1100	735
2-Methylnapthalene	NA	21	1	4.8%	8100D	8100
Naphthalene	NA	21	1	4.8%	2000	2000
Pesticides/PCBs (µg/kg)						
Aroclor-1254	NA	21	1	4.8%	6900D	6900

TABLE 3.1-1 (Concluded)

ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Radionuclides above background UTLs (pCi/g)(5)						
Americium-241	0.01	21	12	57.1%	0.01 - 0.5983	0.090
Plutonium-239	0.02	12	7	58.3%	0.02 - 1.1	0.209
Plutonium-239/240	0.02	9	8	88.9%	0.02855 - 3.12	0.47
Uranium-238	1.5	9	2	22.2%	1.611 - 26.37	14.0
Uranium-233,234	2.5	9	1	11.1%	14.35	14.35
Uranium-235	0.2	9	1	11.1%	0.7509	0.7509
Strontium-90	0.9	21	3	14.3%	0.9 - 1.1	1.0
Tritium (pCi/l)	366	21	1	4.8%	400	400.00

Locations: BH3987, BH4087, 02991, 10191, 12191, 21693, 22493, 24093, 24193, 24493, 24593, 24693, 24793, 25093

NA = not applicable

UTLs = upper tolerance limit

(1) Background concentrations do not exist and are not applicable for organic compounds.

(2) For radionuclides, the number of detections represent only detected concentrations exceeding the background 95% UTL.

(3) B and J qualifiers represent estimated result, D qualifier represents dilution result.

(4) The calculation for the mean concentration includes all J, D, and B qualified data.

(5) Only radionuclides detected above the background UTLs are listed. Number of detection, percent detections, concentration range, and mean concentration refer only to results exceeding background UTLs.

TABLE 3.2-1

OU-2 SUBSURFACE IM/IRA DETAILED SOIL VAPOR SURVEY FIELD REPORT

Location Code	Survey Coordinates		Soil Gas Sample Number	Comment	Sample Depth (ft)	Soil Gas Laboratory Data (µg/L)				
	Easting	Northing				1-1,DCA	CCL_4	TCE	PCE	Total VOCs
111.1-13	2087375	749933	bh36vs01		5.0	0	0	1	0.7	1.7
111.1-14	2087347	749923	bh37vs01		5.0	0	0.47	24	1	25.47
111.1-15	2087319	749912	bh30vs01		5.0	0	11	770	21	802
111.1-16	2087291	749901	bh31vs01		5.0	0	19	514	31	564
111.1-17	2087264	749889	bh19vs01		5.0	14	93	1,023	274	1,404
111.1-18	2087235	749879	bh20vs01		5.0	12	3	2,740	1,670	4,425
111.1-19	2087207	749868	bh23vs02	field replicate	5.0	5.9	0.5	1,670	4,000	5,676.4
111.1-20	2087179	749858	bh24vs01		5.0	0	0.2	110	896	1,006.2
111.1-21	2087150	749849	bh25vs01		5.0	0	0	0.8	4.4	5.2
112-65	2085911	748788	bh40vs01		5.0	0	0.3	4.1	7.7	12.1
112-66	2085908	748814	bh39vs01		5.0	0	0.3	3.2	52	55.5
112-67	2085876	748801	bh38vs01		5.0	0	0	0.97	1.25	2.22
112-68	2085609	749135	bh61vs01		5.0	0	156	1.4	6.8	164.2
112-69	2085616	749035	bh60vs01		5.0	0	90	1.5	5.5	97

TABLE 3.2-1
(Concluded)

Location Code	Survey Coordinates		Soil Gas Sample Number	Comment	Sample Depth (ft)	Soil Gas Laboratory Data (μg/L)				
	Easting	Northing				1-1,DCA	CCL_4	TCE	PCE	Total VOCs
112-70	2085615	748975	bh59vs01		5.0	0	21	0.51	2.2	23.71
112-71	2085661	748957	bh58vs01		5.0	0	31.2	0.64	1.1	32.94
113-34	2086012	749539	bh01vs01		10.0	0	0	0	30	30
113-35	2086033	749569	bh03vs01		10.0	0	0	0	2.7	2.7
113-36	2086057	749563	bh04vs01		10.0	0	0.4	1.1	25	26.5
113-37	2086041	749606	bh05vs01		5.0	0	0	0	0.9	0.9
113-37	2086041	749606	bh05vs02		10.0	0	0	0	4.3	4.3
113-38	2086001	749594	bh02vs01		5.0	0	51	930	2,500	3,481
113-38	2086001	749594	bh02vs02		10.0	0	130	2,600	6,300	9,030
113-39	2086170	749587	bh11vs01		10.0	0	12	3,300	32,400	35,712
113-40	2086150	749588	bh09vs01		10.0	0	0.3	37	3,740	3,777.3
113-41	2086176	749558	bh12vs01		10.0	0	0	1.1	27	28.1
113-42	2086196	749561	bh14vs01		5.0	0	0	0	19	19
113-43	2086202	749586	bh13vs01		5.0	0	0	0	0.96	0.96
113-43	2086202	749586	bh13vs02		10.0	0	0	0	1	1
113-44	2086175	749619	bh10vs01		10.0	0	0	17	415	432

TABLE 3.4-1
OU-2 GEOTECHNICAL RESULTS
(ROCKY FLATS ALLUVIUM AND ARAPAHOE FORMATION)

New Site Number	Work Plan Site Number	Sample Depth (ft BGS)	Sample Strat.	Moisture Content (%)	Dry Density (pcf)	Gradation Gravel (%)	Gradation Sand (%)	Gradation Silt & Clay (%)	Atterberg Limits Liquid Limit (%)	Atterberg Limits Plastic Limit (%)	Atterberg Limits Plastic. Index (%)	Perm.(1) (cm/sec)	Sample Description (USCS Symbol)
03091	30-91	43.7	Ka (No.1)	10.5	129.4	0	54	46	27	15	12	3.1E-9	Clayey Sand, Grey-Brown(SC)
03091	30-91	53.5	Ka (cs)	13.8	114.2	0	5	95	39	14	25	--	Lean Clay, Grey-Black(CL)
03591	35-91	26.5	Qrf	11.4	119.6	0	66	34	33	12	21	--	Clayey Sand, Light Red-Brown(SC)
03591	35-91	37.5	Ka (cs)	18.9	101.8	0	2	98	55	16	39	1.7E-8	Fat Clay, Grey-Brown(CH)
04491	44-91	19.8	Qrf	16.6	94.4	11	45	44	51	16	35	--	Clayey Sand, Orange-Brown(SC)
04491	44-91	26.8	Qrf	18.8	114.3	12	32	56	60	16	44	--	Sandy Fat Clay, Orange-Brown(CH)
05191	51-91	30.5	Qrf	13.3	116.5	0	50	50	40	14	26	1.9E-8	Clayey Sand, Orange-Brown(SC)
05191	51-91	48.5	Ka (cs)	15.1	110.7	0	40	60	36	15	21	--	Sandy Lean Clay, Light Grey(CL)
05191	51-91	50.5	Ka (cs)	20.6	106.9	0	11	89	42	15	27	--	Lean Clay, Grey(CL)
05291	52-91	13.3	Qrf	9.1	104.0	53	30	17	38	16	22	--	Clayey Gravel With Sand, Orange-Brown(GC)
05291	52-91	22.6	Qrf	12.5	119.2	14	56	30	47	16	31	--	Clayey Sand With Gravel, Orange-Brown(SC)
05291	52-91	29.6	Qrf	24.3	95.0	0	35	65	67	20	47	--	Sandy Fat Clay, Orange-Brown(CH)
05291	52-91	31.6	Qrf	18.4	109.4	0	49	51	40	15	25	--	Sandy Lean Clay, Orange-Brown(CL)
06191	61-91	1.6	Qrf	17.2	102.2	12	55	33	41	21	20	--	Clayey Sand, Orange(SC)
06191	61-91	10.7	Qrf	8.8	118.6	34	43	23	--	--	--	--	Clayey Sand With Gravel, Brown(SC)
06191	61-91	23.5	Qrf	5.5	114.8	48	40	12	--	--	--	--	Clayey Gravel With Sand, Orange-Brown(GC)
08591	85-91/BH419	40.7	Qrf	17.0	114.8	14	30	56	44	13	31	--	Sandy Lean Clay With Gravel, Olive-Brown(CL)
10291	BH3091	8.4	Qrf	5.2	--	51	35	14	--	--	--	--	Clayey Gravel With Sand, Orange-Brown(GC)
10291	BH3091	17.8	Ka (cs)	4.9	--	0	35	65	--	--	--	--	Sandy Lean Clay, Brown-Olive(CL)
10291	BH3091	21.8	Ka (cs)	11.5	119.5	0	50	50	30	13	17	--	Sandy Lean Clay, Grey-Brown(CL)
10291	BH3091	37.8	Ka (No.1)	10.3	121.5	0	81	19	28	11	17	3.7E-8	Clayey Sand, Orange-Grey(SC)
10291	BH3091	43.8	Ka (No.1)	14.0	115.3	0	52	48	NP	NP	NP	1.1E-8	Clayey Sand, Light Brown(SC)
10291	BH3091	47.8	Ka (No.1)	12.6	117.8	0	85	15	NP	NP	NP	--	Clayey Sand, Grey-Brown(SC)

(4045-110-0155-571 (GEOTDATA.XLS) (3/23/94 11:01 AM)

TABLE 3.4-1
(concluded)

10291	BH3091	51.8	Ka (No.1)	14.2	119.5	0	31	69	36	13	23	5.0E-9	Sandy Lean Clay, Brown(CL)
10291	BH3091	57.8	Ka (No.1)	12.3	121.9	0	20	80	35	18	17		Lean Clay With Sand, Grey(CL)
10391	BH3191	35.8	Ka (No.1)	17.9	111.8	0	92	8	NP	NP	NP	1.1E-4	Sand With Clay, Grey(SP-SC)
10391	BH3191	61.8	Ka (No.1)	11.2	124.5	0	51	49	29	15	14	7.3E-8	Clayey Sand, Brown(SC)
10691	BH4291	29.0	Qrf	16.2	117.1	49	33	18	--	--	--	--	Clayey Gravel With Sand, Olive-Brown(GC)
10791	BH4391	28.4	Qrf	8.8	116.6	17	55	28	--	--	--	--	Clayey Sand With Gravel, Orange-Brown(SC)
10791	BH4391	33.8	Qrf	20.3	107.5	0	47	53	49	15	34	--	Sandy Lean Clay, Brown-Olive(CL)
10791	BH4391	37.3	Qrf	12.7	118.8	10	58	32	29	13	16	--	Clayey Sand, Orange-Brown(SC)
10891	BH4491	16.7	Qrf	15.4	105.7	15	52	33	45	17	28	--	Clayey Sand, Orange-Brown(SC)
10891	BH4491	25.8	Qrf	16.3	111.3	0	58	42	40	16	24	1.2E-8	Clayey Sand, Orange-Brown(SC)
20091	NA	28.1	Qrf	10.2	124.9	0	61	39	35	14	21	1.3E-7	Clayey Sand, Brown(SC)
20091	NA	40.7	Ka (No.1)	11.9	121.4	0	45	55	29	22	7	5.4E-8	Sandy Silty Clay, Brown(CL-ML)
20091	NA	49.6	Ka (No.1)	12.3	119.1	0	53	47	24	19	5	1.5E-7	Silty Clayey Sand, Brown(SC-SM)
20791	NA	15.3	Qrf	13.1	109.1	16	65	19	38	15	23	2.2E-8	Clayey Sand With Gravel, Brown(SC)
20791	NA	20.9	Qrf	8.0	147.2	56	36	8	34	16	18	--	Gravel With Clay and Sand, Brown(GP-GC)
20991	NA	42.8	Ka (No.1)	15.1	113.7	55	41	4	NP	NP	NP	1.1E-6	Gravel With Sand, Brown(GP)
20991	NA	56.8	Ka (No.1)	13.4	117.1	0	49	51	29	14	15	6.8E-8	Sandy Lean Clay, Brown(CL)
20991	NA	60.5	Ka (No.1)	--	--	42	51	7	--	--	--	--	Sand With Clay & Gravel, Yellow-Brown(SP-SC)

Notes :

BGS - Below Ground Surface	Ka - Arapahoe Formation	Perm. - Permeability
BH - Borehole	NA - Not Applicable	Plastic. Index - Plasticity Index
(cs) - Claystone	No. 1 - No. 1 Sandstone	Sample Strat. - Sample Stratigraphy
Qrf - Rocky Flats Alluvium	NP - Non-Plastic	

The symbol "--" indicates that the tests were not conducted on that sample.

(1) Permeability tests were conducted using the fixed-wall, falling-head method at 20 degrees C.

4.0 BASIS OF DESIGN FOR OFFGAS TREATMENT

The following sections detail the design criteria used in the design development of the offgas treatment alternative. These criteria include offgas treatment unit inlet and discharge conditions, requirements and limitations of the pilot test wells and power supplies, and consideration of by product generation and disposal.

4.1 REGULATORY REQUIREMENTS

The following sections describe the air emission requirements and RCRA requirements that may be applicable to the existing SVE system and potential offgas treatment alternatives used for the pilot tests. Several of the offgas treatment alternatives could meet the definitions of RCRA regulated units and might require more stringent destruction and removal efficiencies (DREs).

4.1.1 Air Emission Requirements

Cleanup activities from contaminated sites, Resource Conservation Recovery Act (RCRA) corrective actions, and facility closures can result in the release of emissions to the atmosphere. Remediation activities in these cases involve the cleanup of contaminated soil. Soil vapor extraction (SVE) has proved to be effective for the removal of VOC and light petroleum hydrocarbons from subsurface soils. The extracted air is usually treated for VOC removal prior to discharge to the ambient air to prevent air pollution problems.

The contaminants of concern for the Rocky Flats Plant (RFP) SVE pilot test site are tetrachloroethylene (PCE), carbon tetrachloride (CCl_4), 1,1-dichloroethane (1,1 DCA), and trichloroethylene (TCE). Also, small quantities of oxides of nitrogen (NO_x) and hydrochloric acid (HCl) would be released from offgas equipment. The five compounds with exception of the NO_x emissions are listed as hazardous air pollutants (HAPs).

The regulatory requirements for these potential pollutants have been reviewed and are summarized below. These requirements include initial reporting to Colorado Department of Health (CDH) for submittal of an Air Pollution Emission Notice (APEN). As defined by the CDH in Regulation 3 (August 30, 1993), the contaminants of concern for the pilot test site are categorized as Hazardous Air Pollutants (HAPs) and are assigned as Bin A (PCE and CCl_4), Bin B (1,1DCA), and Bin C (TCE). The level at which emissions from the offgas treatment system would require reporting (submittal of a CDH APEN for each Bin) are:

- Bin A - 250 lbs/yr
- Bin B - 2500 lbs/yr
- Bin C - 5000 lbs/yr

Table 4.1-1 provides the average and maximum emission rates and estimates the control efficiency required to produce annual emission rates below the maximum APEN reporting rate. If the annual emission rate for each constituent is below the applicable reporting level, then an APEN is not required for that particular HAP.

Table 4.1-2 provides the average and maximum emission rates and estimates of the control efficiency required to produce annual emission rates below the maximum reporting limit that triggers submittal of a CDH Construction Permit Application. Because Jefferson County is currently nonattainment for ozone, construction permits are required for VOC emissions greater than 2 tons per year. If the annual emission rate for each constituent is below the applicable BIN limit, then a Construction Permit is not required for that particular HAP.

Plant wide emissions of nitrogen oxides are well below the 250 tpy, which designates a major source. Therefore, NO_x emissions associated with the pilot plant would need to exceed the requirements for criteria pollutants to require filing an APEN (greater than 2 tons per year) or a CDH construction permit (greater than 10 tpy).

For the purpose of these pilot tests, the capture efficiency of VOCs to be applied as criteria for an offgas treatment system should meet reasonably achievable control technology (RACT). Removal efficiencies achieved should be those commonly achieved by similar equipment used in other applications.

4.1.2 RCRA Requirements

RCRA regulates the management of hazardous waste, including the storage, treatment, and disposal of hazardous waste. Hazardous waste is a subset of solid waste. Solid waste is defined by the RCRA statute as "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material including solid, liquid, semisolid, or contained gaseous material . . ." Uncontained gases are not regulated by RCRA. It is EPA's policy that offgases from the treatment of hazardous waste are regulated under RCRA under the derived-from rule. Thermal treatment units, depending on the type of unit and how it operates, can be regulated units under RCRA. 40 CFR Part 264 contains the standards for regulated units. 40 CFR Part 266 contains standards for recycling units. Boilers and industrial furnaces are regulated under Part 266, Subpart H. Part 264, Subpart O contains the incinerator standards. Other types of thermal treatment units that do not qualify as either incinerators or boilers/industrial furnaces could be regulated as miscellaneous units under Part 264, Subpart X.

The following regulatory definitions (40 CFR Part 260.10) are relevant to this discussion:

- Incinerator means any enclosed device that (1) uses controlled flame combustion and neither meets the criteria for classification as a boiler, sludge dryer, or carbon regeneration unit, nor is listed as an industrial furnace; or (2) meets the definition of infrared incinerator or plasma arc incinerator.

- Infrared incinerator means any enclosed device that uses electric powered resistance heaters as a source of radiant heat followed by an afterburner using controlled flame combustion and which is not listed as an industrial furnace.

- Plasma arc incinerator means any enclosed device using a high intensity electrical discharge or arc as a source of heat followed by an afterburner using controlled flame combustion and which is not listed as an industrial furnace.

- Boiler means an enclosed device using controlled flame combustion and having the following characteristics: (1) the unit must have physical provisions for recovering and exporting thermal energy in the form of steam, heated fluids, or heated gases . . .

- Industrial furnace means certain enclosed devices that are integral components of manufacturing processes and that use thermal treatment to accomplish recovery of materials or energy.

It appears that the plasma oxidation and thermal oxidation technologies under consideration would meet the RCRA definition of incinerator. The other options, flameless thermal destruction and catalytic oxidation, would probably be regulated as miscellaneous units.

The incinerator standards in 40 CFR Part 264 Subpart O contain a section on performance standards (Section 264.343). For hazardous waste (except dioxin wastes), the incinerator must meet a destruction and removal efficiency (DRE) of 99.99 percent for each principal organic hazardous constituent. The miscellaneous unit standards have a general environmental performance standard in Section 264.601. This standard does not have specific DRE requirements but does, however, allow the requirements of Part 264, including Subpart O, to be applied if they are appropriate for the miscellaneous unit being permitted.

In addition, RCRA regulates air emissions from process vents (40 CFR Part 264, Subpart AA) and equipment leaks (40 CFR Part 264, Subpart BB) at RCRA treatment, storage, disposal (TSDs). The process vent standards apply to process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, or air or steam stripping operations that manage hazardous waste with organic concentrations of at least 10 ppm if these operations are conducted in units that are subject to RCRA permitting or hazardous waste recycling units. Closed-vent systems and control devices used to comply with the provisions of Subpart AA are regulated at 264.1033. Enclosed control devices (e.g., a vapor incinerator, boiler, or process heater) must reduce organic emissions vented to it by 95 weight percent or greater; achieve a total organic compound concentration of 20 ppmv; or provide a minimum residence time of 0.50 seconds at a minimum temperature of 760 degrees C.

RCRA does have a treatability study exemption for small-scale treatability studies. The exemption is contained in 40 CFR 261.4(e and f). New quantity limits were recently established in a February 18, 1994 Federal Register. The new quantity limit is no more than 10,000 kilograms of contaminated media (i.e., soil or groundwater) with nonacute hazardous waste.

Finally, RCRA also has provisions for research, development, and demonstration permits for hazardous waste treatment facilities that propose to use an innovative and experimental technology or process. The standards for these permits are in 40 CFR 270.65. No amounts are specified and the requirements are case-specific and site-specific.

4.2 PILOT TEST NO. 1 SVE CRITERIA

Soil gas is extracted from the alluvium through extraction well AV1 or the sandstone through extraction well SV1. The air stream is pulled through a demister in the knockout drum to remove entrained moisture. The stream then passes through High Efficiency Particulate Air

(HEPA) filters to ensure that the discharged soil gas stream is free of radionuclide-contaminated particulates. Finally, the air stream passes through two vapor phase granular activated carbon GAC units (in series) for VOC removal. The treated air stream is then discharged.

The SVE pilot unit is a transportable unit consisting of the following major pieces of equipment as shown on Figure 4.2-1:

- Knockout drum
- Liquid transfer pump
- HEPA filters (3)
- Blowers (2)
- GAC units (2)
- Air injection blower
- Storage tanks (2)

4.2.1 SVE Design Criteria

The SVE pilot unit was designed according to the criteria summarized in Table 4.2-1.

The SVE pilot unit was designed to a National Electric Code (NEC) Class I Div. II electrical classification. The system is currently powered by a 125 kW transportable diesel generator. Electrical requirements are 460 volts/3 phase/60 Hz.

4.2.2 Pilot Test No. 1 Operating Criteria

Pilot Test No. 1 will test the SVE technology under nine different sets of operating conditions to evaluate the system's performance. This series of tests will require four to six weeks (200 hours) of treatment system operations, with weekly operating times of approximately forty hours.

Pilot Test No. 1 will also test sustained operations for one or two extraction wells. Sustained operations of the SVE system will continue for 6 weeks, for a total operating time of 1,008 hours.

The inlet conditions of the soil vapor airstream to the offgas treatment system for Pilot Test No. 1 are listed in Table 4.2-2. The values in the table are from preliminary test data, except for the maximum values for each condition.

High concentrations of contaminants in the inlet airstream (AV1) could occur as shown on Table 4.2-3. High VOC loading can damage the existing treatment system (granular activated carbon unit) and compromise worker safety. Dilution air is introduced to the inlet airstream to prevent these occurrences. Table 4.2-4 shows the conditions of the make-up air and also the combined flow rate conditions.

The gas stream through the SVE combines extracted soil gas and make-up air. The blowers are located upstream and downstream from the GAC units. Recent pilot test data (Table 4.1-8) have shown the discharge pressure and temperature from the first blower (B300) to be 5 to 7 in Hg vacuum and 90 to 120°F. Discharge conditions from the exhaust blower (B500) are 0.1 to 0.3 psig and 125 to 150°F. The discharge flowrate from the system has been 300 to 350 scfm.

The GAC unit removes greater than 99 percent of the contaminants from the gas stream. Table 4.2-5 contains maximum concentrations of each of the most prevalent VOCs and the corresponding removal rates for the contaminants. In addition, the water vapor extraction rate is listed since it will affect the GAC loading for the VOCs of interest.

Operation of the SVE system produces three discrete by-products. Extracted groundwater from the water knockout drum that may be contaminated with entrained VOCs and possibly radionuclides. The HEPA filters that were installed to collect particulates, possibly including radionuclides, are another waste component. The third by-product is the saturated GAC material. Each of these waste products must be stored, treated, and/or disposed of on or offsite.

4.3 PILOT TEST NO. 2 SPSH CRITERIA

The SPSH technique is based on the ability to split conventional three-phase electricity into six separate electrical phases. Each phase is delivered to a single electrode, requiring six electrodes placed in a circle. Because each electrode is at a separate phase, each one conducts to all the others. This provides for more uniform heating of the soil to be treated.

The design criteria for the offgas from the SPSH are summarized in Table 4.3-1.

The SPSH Pilot Test No. 2 will be conducted at the same location a Pilot Test No. 1, Trench T-3 (IHSS 110). Pilot Test No. 2 will incorporate the existing SVE equipment into the design of the test. The Test No. 2 will operate for 45 days (1080 hours) with an additional 45 days (1080 hours) for the cool down period.

Power requirements for this system are approximately 300 to 500 kW for the SPSH alone. Additional power will be required for the SVE and offgas treatment systems.

4.4 SVE, SPSH, AND OFFGAS TREATMENT WASTE BY-PRODUCTS

During normal operation of the pilot tests by-products are generated. The SPSH will be generating a large quantity of steam during operation. The first step in the extraction process will be to condense the steam to a liquid. This condensate will require storage and potential treatment prior to disposal. A total of approximately 45,000 gallons of condensate is estimated to be produced. The average flow rate is anticipated to be 2.5 to 3 gpm.

In addition to the condensate, wastes will be generated by SVE and SPSH that require further treatment and/or disposal. Water in the soil vapor air stream will be removed and collected prior to treatment of the air stream. This water may contain VOCs and require treatment prior to disposal. The SPSH would also generate a larger quantity of water potentially contaminated with VOCs. The options for treatment and disposal of this water include the following:

- 881 Hillside water treatment unit (ultraviolet [UV] oxidation and ion exchange)
- OU-2 Field Treatment Unit (precipitation, membrane filtration, GAC)

Both of these options are existing treatment units with limited capacity and capabilities. Other options would involve addition of a new treatment system such as air stripping.

Other waste by-products of the existing system include the HEPA filters and the spent GAC. The used HEPA filters would be stored on site until further disposal disposition has been determined. The GAC would be removed from the vessel and stored in drums onsite.

During the SPSH, higher concentrations of VOCs are anticipated to be removed from the soil. Some of the offgas options would involve condensing the VOCs, thus producing a quantity of concentrated organic liquid. This organic liquid would require further treatment and/or disposal.

Some of the offgas treatment systems produce hydrogen chloride (HCl) in the offgas stream. The HCl is scrubbed with caustic to remove the chlorides. This further treatment produces a spent caustic solution which will require treatment prior to disposal or storage.

4.5 OTHER CRITERIA

In addition to the above design criteria, several other general criteria are important to the selection and design of the offgas treatment system. The future system should be portable to enable the complete treatment system to be moved to another site at RFP. The future offgas treatment should incorporate the existing SVE system and be amenable to retrofitting the existing system. The system should be self contained and require minimal utility hookups from the RFP site.

4.6 EXISTING OFFGAS TREATMENT

The existing offgas treatment system for SVE is a vapor phase granular activated carbon (GAC) system. The GAC system (D-400, D-410) is used to remove organic contaminants from the extracted vapor. The carbon steel vessels are four feet in diameter, approximately 7.5 feet tall, with a lined interior for corrosion protection. The vessels are ASME code stamped and rated for full vacuum. Basic design limits on the vessels are as follows in Table 4.6-1.

Each column contains approximately 1,800 pounds of coconut based activated carbon (Westates VACarb or equivalent). Specifications for the carbon are as follows:

Size (U.S. Sieve)	4 x 8
Type	Coconut Shell
Hardness no. (min., wt.%)	97
Ash (max., wt.%)	2
Moisture (max. as packaged, wt.%)	2
CCl_4 Activity (Min.)	62%
Iodine No. (Min.)	1,000
Retentivity (wt.%)	40

Surface area (B.E.T)	1250 m^2/g
Pore Volume	0.55 cc/g
Mean particle diameter	3.4 mm
Apparent density	29 lb./ft^3

The GAC units are operated in series. The performance of the vapor-phase GAC units will be estimated based on the results obtained throughout the duration of all nine system pilot tests. System variables, such as relative humidity and temperature of the extracted vapor stream, will affect the performance of the GAC units. Contaminant mass-removal rates will determine the mass loading rate. GAC isotherms for the compounds extracted will be used to estimate the carbon unit lifetime. An estimate of carbon usage for Pilot Test No. 1 is shown in Table 4.6-2.

TABLE 4.1-1

COMPARISON OF EMISSIONS RATES TO CDH AIR POLLUTANT EMISSION NOTICE (APEN) CRITERIA

Contaminant	Uncontrolled Average Extract Rate (lbs/hr)	Uncontrolled Average Extract Annual Rate (lbs/yr)	Control Eff Average Below APEN Report Rate (%)	Uncontrolled Max Extract Rate (lbs/hr)	Uncontrolled Max Extract Annual Rate (lbs/yr)	Control Eff Max Below APEN Report Rate (%)	Max APEN Reporting Rate (lbs/yr)
Bin A							
PCE	36.38	78,570.43	99.68%	48.23	104,184.39	99.76%	250
CCl_4	0.24	526.56	52.54%	0.32	698.22	64.21%	250
Bin B							
1,1 DCA	0.89	1,919.25	0.00%	1.18	2,544.92	1.77%	2,500
Bin C							
TCE	0.21	449.18	0.00%	0.28	595.62	0.00%	5,000

* Operating Scenario: 3 months (2,160 hours), 24 hours per day, 7 days per weeks

TABLE 4.1-2

COMPARISON OF EMISSIONS RATES TO CDH CONSTRUCTION PERMIT (C.P.) CRITERIA

Contaminant	Uncontrolled Average Extract Rate (lbs/hr)	Uncontrolled Average Extract Annual Rate (tons/yr)	Control Eff Average Below C.P. App Rate (%)	Uncontrolled Max Extract Rate (lbs/hr)	Uncontrolled Max Extract Annual Rate (tons/yr)	Control Eff Max Below C.P. App Rate (%)	Max C.P. Applicability Rate (tons/yr)
Bin A							
PCE	36.38	39.29	94.91%	48.23	52.09	96.16%	2
CCl_4	0.24	0.26	0.00%	0.32	0.35	0.00%	2
Bin B							
1,1 DCA	0.89	0.96	0.00%	1.18	1.27	0.00%	2
Bin C							
TCE	0.21	0.22	0.00%	0.28	0.30	0.00%	2
Total VOCs	38	41	95.09%	50	54	96.30%	2

* Operating Scenario: 3 months (2,160 hours), 24 hours per day, 7 days per weeks

TABLE 4.2-1

SVE DESIGN CRITERIA

	Average	Maximum
Airflow Rate	300 scfm	600 scfm
Pressure/Vacuum	5 to 8 in Hg vacuum	10 in Hg vacuum
Temperature		
Blower B300	300 scfm	600 scfm 15 in Hg vacuum 100°F temp rise
Blower B500	300 scfm	500 scfm 18 in Hg 60°F temp rise
HEPA filters		
FL-200		500 scfm
FL-210		125 scfm
FL-220		500 scfm 10 in Hg operating vacuum
Knockout Drum	100 gal	150 gal 650 scfm 15 in Hg operating vacuum

TABLE 4.2-2

INLET CONDITIONS OF EXTRACTED SOIL GAS

Parameter	Minimum	Maximum	Average
Pressure (in. Hg vacuum)[1]	2	10	9.8
Flow Rate (scfm)	4	100	11.4
Relative Humidity (%)	5	100	17.8
Temperature (°F)	30	60	43.0

1 The values for pressure measure the pressure drop, in inches of mercury, below one atmosphere, or 29.9 in Hg.

TABLE 4.2-3

AVERAGE VOC CONCENTRATIONS FROM COMPLETED PILOT TEST DATA

	AV1 (ppb)	Make Up Air (ppb)	Blower 300 (ppb)
Analyte	Average Concentration[1]		
CCl_4	577,500	.93	29,285
PCE	747,500	110.67	37,314
Total VOCs	1,402,250	116.60	70,632

[1] Based on Pilot Test No. 2-3, raw data that has not been validated.

TABLE 4.2-4

DESIGN INLET CONDITIONS OF MAKE-UP AIR

Parameter	Minimum	Maximum	Average
Flow Rate (scfm)	200	500	275
Relative Humidity (%)	8	100	10
Temperature (°F)	-10	110	60
Combined Flowrate (scfm)	300	600	310

TABLE 4.2-5

OPERATING CONDITIONS FROM COMPLETED PILOT TEST DATA

Location	P (in Hg)	ΔP (in Hg)	T (°F)	ΔT (°F)	RH (%)	Δ RH (%)	F (scfm)
Extraction Well (110)	-9.79	NA	23.8	NA	58.6	NA	11.43
Make Up Air (100)	-9.72	NA	24.0	NA	56.9	NA	272.86
Before HEPA Filter (200)	-10.58	-0.86	25.5	5.5	39.4	17.5	--
After HEPA Filter (201)	-10.83	-0.25	--	NA	--	NA	--
After Blower 300 (300)	-5.57	+5.26	101.5	76	3.13	36.3	--
After GAC 1 (400)	-3.79	+1.78	102[2]	0.5	--	NA	--
After GAC 2 (410)	-4.21	-0.42	86.3[2]	15.7	--	NA	--
After Blower 500 (500)	+.03	+4.24	138.3	52	--	NA	310.86

P = Pressure
ΔP = Pressure Change
T = Temperature
ΔT = Temperature Change
RH = Relative Humidity
ΔRH = Relative Humidity Change
F = Flow Rate

[1] Based on data from Pilot Test Nos. 2-3 and 3-2.
[2] Temperature measured in GAC unit prior to discharge.

TABLE 4.3-1

DESIGN CRITERIA FOR SPSH

	Average	Maximu	Design
Total flowrate (scfm)	300	500	300
Air flowrate (scfm)	150	50	150
Water vapor flowrate (scfm, gpm)	150 (0.8)	450 (2.5)	150 (2.5)
Temperature (°F)	150	212	150
Pressure (inches Hg vacuum)	15	15	15
VOC concentration (ppmv)	5,000	20,000	6,500
VOC removal rate (lbs/hr)	20 - 30	260	50
Total volume water generated (gallons)	-	45,000	45,000

TABLE 4.6-1

GAC DESIGN CRITERIA

	Avg.	Max.
Flow Rate	300 scfm	600 scfm
Temperature	70°F	200°F
Pressure	8" Hg	10" Hg
ΔP	--	1.5 psi

TABLE 4.6-2

ESTIMATED CARBON USAGE

PILOT TEST NO.	AVERAGE VOC CONCENTRATION (ppm/v)	AVERAGE VOC CONCENTRATION (ug/l)	AVERAGE FLOW RATE (scfm)	AVERAGE VOC REMOVAL FLOW RATE (lbs/hr)	HOURS OF OPERATION	LBS OF VOC REMOVED
1	1600	10872	6	0.24	4	1
2	1950	13250	13	0.64	55	35
3	700	4757	1	0.02	48	1
4	700	4757	7	0.12	48	6
5	1950	13250	16	0.79	16	13
6	2100	14270	18	0.96	16	15
7	800	5436	9	0.18	16	3
8	2100	14270	20	1.07	16	17
9	800	5436	11	0.22	16	4
					TOTAL LBS VOCS =	95

5.0 TECHNOLOGY IDENTIFICATION AND SCREENING

This section presents the potentially applicable technologies for treatment of VOCs in a gas stream. Each technology will be reviewed and discussed in general terms. The technologies will undergo a preliminary screening with respect to effectiveness and implementability. The technologies that pass the preliminary screening will be used to develop alternatives for the removal of VOCs from extracted soil gas. The alternatives will be reviewed and further evaluated with respect to the following criteria: effectiveness, implementability, and cost.

5.1 TECHNOLOGY IDENTIFICATION AND DESCRIPTION

Table 5.1-1 presents the list of potentially applicable technologies for treatment of VOCs in air streams. These technologies are discussed in the following sections.

5.1.1 Granular Activated Carbon (GAC)

The GAC technology is presently used for offgas treatment with the existing SVE pilot test unit. GAC media remove vapor-phase VOCs from gas streams by adsorption. The gas stream is passed through a packed column(s) of GAC media and the treated gas is discharged to the atmosphere. The VOC loading rates for the GAC media vary depending on the vapor phase constituents and their inlet concentrations. Once the GAC media are saturated and VOC breakthrough occurs, the GAC media are replaced. The media are typically regenerated or disposed of off site. Regenerated media can subsequently be reused as treatment media. However, VOC loading capacities for the regenerated GAC are reduced through continued regeneration and recycling.

GAC has been proven to be very effective at removing VOCs from gas streams in SVE systems. However, high concentrations and flow rates can quickly saturate the GAC media.

5.1.2 Membrane Separation

The membrane separation process is based on condensation and selective membrane permeability to VOCs versus oxygen, nitrogen, and other gases. The extracted gas is first compressed to 150 pounds per square inch (psig) and then cooled to approximately 35 °F in a refrigerant cooled heat exchanger. Condensate is collected and removed. The uncondensed stream then enters the membrane unit and is separated into a VOC rich stream and a VOC depleted stream. The VOC rich stream is routed back to the soil gas stream prior to the compressor. The VOC depleted stream is then passed through GAC to remove the remaining VOCs. VOC removal is approximately 95 percent prior to GAC treatment.

5.1.3 Biofiltration

Biofiltration was developed for the removal of organics from gas streams. The air stream passes through activated carbon media and adsorbs the VOCs. Microbes on the activated carbon media biologically reduce the VOCs to water and carbon dioxide. Biofiltration has not been demonstrated to process halogenated VOCs.

5.1.4 Chemical Reduction

A gas-phase thermo-chemical reduction reaction of hydrogen with chlorinated organic compounds at elevated temperatures produces lighter, smaller hydrocarbons. The products are primarily HCl, hydrogen and methane. The reaction is enhanced by the presence of water. The waste stream is preheated to 302°F and then transferred to the reactor where it is heated to 1652°F. The stream then passes through a scrubber where the HCl, heat, particulates, and water are removed. Ninety-five percent of the scrubber stream (primarily hydrogen and methane) is circulated back to the reactor. The remaining 5 percent is used for fuel for preheating the waste. Chemical reduction can not process streams containing oxygen.

5.1.5 Photo-dehalogenation

The process converts volatile halogenated compounds to less halogenated compounds or fully dehalogenated compounds by initiating reactions in a reducing atmosphere with ultraviolet light. The process inputs are hydrogen or natural gas, heat, and ultraviolet light. The primary products are dehalogenated organics and HCl. Therefore, a caustic scrubber will be needed to remove the HCl prior to venting, and a secondary treatment will be needed to process the dehalogenated volatiles.

5.1.6 Ozone-UV-Granular Activated Carbon (GAC)

The ozone-UV-GAC system is comprised of three unit processes, including a gas phase photolytic reactor chamber, a mist air dispersion reactor, and two GAC adsorption beds. The airstream first enters the photolytic reaction chamber, where the VOCs are oxidized in the presence of ozone and ultraviolet light. The mist air dispersion reactor ensures the minimum humidity level, in addition to scrubbing out HCl which is a by-product of the photolytic reactor. Finally, the air stream passes through the GAC bed which adsorbs any remaining contaminants. Dual GAC units are installed to provide treatment while one bed is being regenerated. The off-line GAC bed undergoes regeneration, where the GAC column is heated and flushed to desorb the contaminants. This desorbed gas stream is cycled back into the photolytic reactor inlet and reprocessed.

5.1.7 Adsorption/Condensation

This process is based upon VOC adsorption, bed regeneration, and VOC condensation and collection. The gas stream is passed through a packed bed of proprietary synthetic resin removing VOCs. Once the bed is loaded, the offgas is diverted to a fresh bed. The loaded bed is regenerated by heating and flushing with nitrogen. The VOCs are then condensed and transferred to a storage tank from the flush gas. VOC removal is greater than 99 percent.

5.1.8 Condensation

The stream is passed through series of heat exchanger(s) to cool the gas and condense water and VOCs from the extracted soil gas stream. The cooling process can be accomplished in several steps and can use a combination of air heat exchangers, water heat exchangers, and refrigeration units. The treated stream will require a secondary treatment to remove the residual VOCs (e.g., GAC, catalytic oxidation, etc.).

5.1.9 Flameless Thermal Destruction

Flameless thermal destruction is a packed bed thermal oxidizer operating at 1600°F to 2000°F. An inert ceramic matrix is used as the packing material to enhance fume mixing and also provide thermal inertia. A destruction removal efficiency (DRE) of greater than 99 percent with negligible NO_x and CO production is achievable. An enthalpy content of the gas greater than 30 British Thermal Units per standard cubic feet (BTU/scf) will be self-sustaining once operating conditions are met (i.e., no supplemental fuel is required). Prior to operations, the packing material is preheated by a combustion system or electric heaters. The process is currently used for fugitive VOC emission and process offgas abatement. Because the SVE offgas contains chlorinated organics, hydrogen chloride (HCl) will be produced and a caustic scrubber will be necessary to remove and neutralize the HCl prior to discharging the offgas to the atmosphere.

5.1.10 Thermal Oxidation

Thermal oxidation destroys the VOCs by oxidizing the gas stream at temperatures of 1600°F to 2000°F with a residence time of approximately 2 seconds. The oxidation system requires supplemental fuel to increase the gas temperature for treatment. HCl gas is produced, requiring removal and neutralization prior to discharge to the atmosphere.

5.1.11 Catalytic Oxidation

Catalytic oxidation is a process by which VOCs are oxidized in the presence of a catalyst. The offgas is heated to approximately 700°F and passed over a catalyst where it is oxidized to carbon dioxide, water, and HCl. Catalytic oxidation is particularly effective when the treatment stream contains dilute contaminants (i.e., less than 1000 ppm v/v) due to the lower operating temperature (approximately 700°F) required for oxidation (thermal incinerators typically run greater than at 1600 °F). High contaminant loading rates may cause heat build-up within the catalyst. However, if the contaminant loading rate is known, the system can be designed to alleviate the heat build-up. The process is continuous and can be implemented either as a once-through process or using recuperative heat exchange to lower operating costs. Conversion efficiencies can range from 90 to greater than 99 percent removal of contaminants depending on residence time and the specific catalyst.

5.1.12 Plasma Oxidation (High Energy Corona)

A high voltage current is arced through the treatment stream to ionize air which produces a low temperature (near ambient temperature) plasma that destroys organics (Battelle 1993). VOC destruction in pilot testing was greater than 99 percent with a residence time of 15.7 seconds. The system requires controlled humidity (~45 percent RH) to control static charge accumulation and sparking. The formation of significant levels (e.g., 5 ppm v/v carbon tetrachloride) of by-products at higher levels of humidity (90 percent RH) has been observed. Because the SVE offgas contains chlorinated organics, HCl will be produced and a caustic scrubber will be necessary.

5.2 SCREENING OF POTENTIALLY APPLICABLE TECHNOLOGIES

5.2.1 Screening Criteria

The technologies were screened with respect to two major criteria: effectiveness and implementability. These criteria were defined as follows:

Effectiveness:

1. Removal Efficiency - How effective is the technology at removing the contaminants of concern?
2. Potential to meet the cleanup goal - Is the technology capable of removing the contaminants of concern?

Implementability:

1. Is the technology compatible with the existing SVE unit to minimize modifications to the process system?
2. Technology maturity for specific contaminant - At what level of development is the technology (e.g., emerging, commercially available, etc.)?
3. Operations - What items are necessary for operation and maintenance of the technology (e.g., incineration requires combustion fuel)?
4. Adverse impacts - If the technology is implemented, what wastes will be generated?

5.2.2 Technology Screening

Table 5.2-1 resents the list of potentially applicable technologies for treating the OU-2 SVE offgas. Evaluation comments regarding the effectiveness and implementability of the technologies are presented and each technology is characterized as either retained or not retained for further evaluation.

Granular Activated Carbon (GAC) with Offsite Regeneration or Disposal

Vapor phase GAC is presently used to treat the SVE offgas. It is effective for treatment of the contaminants of concern, but may need to be replaced frequently due to high VOC loading rates. Since this technology is currently in the treatment train, it will serve as the no action alternative. This technology will be retained to serve as a baseline condition for comparison of alternatives.

Membrane Separation

This technology alone does not have the potential to meet cleanup goals. GAC polishing would have to be added to treatment train to obtain the required removal efficiency for VOCs. Membrane separation is commercially available but not readily compatible with the SVE unit at OU-2. Therefore, this technology will not be retained for further consideration.

Biofiltration

This technology is not applicable to the contaminants of concern in the OU-2 air stream. Based on effectiveness, this technology will not be retained for consideration as part of a remedial action alternative.

Chemical Reduction

This technology is not effective for treatment of air streams containing oxygen. Therefore, chemical reduction will not be retained for further consideration.

Photo-dehalogenation

This technology is applicable for reducing the VOCs in the OU-2 air stream, although secondary VOC treatment would be required. The technology is emerging, so removal efficiency is unknown and equipment is not readily available. Based on both effectiveness and implementability, this technology will not be retained.

Ozone-UV-GAC

This technology is effective in treating the contaminants of concern in the OU-2 air stream. It is commercially available and compatible with the existing SVE unit. This technology will be retained for further consideration.

Adsorption/Condensation (PURUS)

This technology provides a greater than 99 percent removal efficiency for the contaminants of concern in the OU-2 air stream. The equipment is compatible with the existing SVE unit and readily available. Therefore, this technology will be retained for consideration as part of a remedial action alternative.

Condensation

This technology is applicable for treatment of the contaminants of concern in the OU-2 air stream. Although the addition of polishing GAC would be required to achieve the required cleanup goal, this technology is compatible with the existing SVE unit and will be retained for further consideration.

Flameless Thermal Destruction

This technology has a greater than 99 percent removal efficiency for the OU-2 air stream contaminants of concern. Although caustic scrubbing is required, this technology is available and compatible with the existing SVE unit and little or no supplemental fuel is required if the enthalpy content of the gas is high enough. This technology will be retained for further consideration.

Thermal Oxidation

This technology is effective for treating the OU-2 air stream to meet cleanup goals. Although this technology requires a fuel source for combustion and a caustic scrubber, it is commercially available and compatible with the existing SVE unit. This technology will be retained for further consideration.

Catalytic Oxidation

This technology has the potential to meet the cleanup goal, but is more applicable to dilute contaminant streams (i.e., less than 1000 ppm v/v). Although this technology requires a fuel source for combustion and a caustic scrubber, it is compatible with the existing SVE unit and available. This technology will be retained for further consideration.

Plasma Oxidation (High Energy Corona)

This technology is applicable to the OU-2 air stream contaminants of concern. Although this is an emerging technology, it has been pilot tested with an SVE unit and is compatible with the existing SVE unit. This technology will be retained for further evaluation.

5.2.3 Retained Technologies

As shown on Table 5.2-1, the following technologies will be retained for consideration as part of remedial action alternatives:

- GAC
- Ozone-UV-GAC
- Adsorption/Condensation (PURUS)
- Condensation
- Flameless Thermal Destruction
- Thermal Oxidation
- Catalytic Oxidation
- Plasma Oxidation (High Energy Corona)

TABLE 5.1-1

POTENTIALLY APPLICABLE TECHNOLOGIES

Granular Activated Carbon
- Offsite Regeneration
- Offsite Disposal
- Onsite Regeneration

Membrane Separation
Biofiltration
Chemical Reduciton
Photo-dehalogenation
Ozone-UV-Granular Activated Carbon
Adsorption/Condensation (Purecycle)
Condensation
Flameless Thermal Oxidation
Thermal Oxidation
Catalytic Oxidation
Plasma Oxidation (High Energy Corona)

TABLE 5.2-1

PRELIMINARY TECHNOLOGY SCREENING SVE OFFGAS

	Effectiveness			Implementability				
Technology	**Applicability**	**Removal Efficiency**	**Potential to Meet Cleanup Goal**	**Technology Maturity**	**O&M Requirements**	**Implementability**	**Adverse Impacts**	**Retain Yes/No**
GAC with off-site regeneration or disposal	Applicable to contaminants of concern. More applicable to low loading rates.	Greater than 99 percent	Yes. May require large quantities of GAC because of high loading rates.	Commercially available	Remove and replace spent GAC.	Currently in the SVE treatment train. Impractical because of anticipated high loadings.	Spent GAC	Yes
Membrane Separation	Applicable to chlorinated and non-chlorinated volatile organics.	95 percent removal (GAC polishing would improve the removal efficiency)	Yes, with GAC polish	Commercially available	Large power supply for the compressor, vacuum pumps, and refrigeration.	Equipment available. Technology is not readily compatible with the SVE unit.	GAC polishing required; A VOC contaminated aqueous phase and potentially an organic phase.	No
Biofiltration	Cannot process contaminants of concern	N/A	No	N/A	N/A	N/A	N/A	No
Chemical Reduction	Cannot be used to process streams with oxygen	N/A	N/A	N/A	N/A	N/A	N/A	No

TABLE 5.2-1

PRELIMINARY TECHNOLOGY SCREENING SVE OFFGAS

	Effectiveness			Implementability				
Technology	**Applicability**	**Removal Efficiency**	**Potential to Meet Cleanup Goal**	**Technology Maturity**	**O&M Requirements**	**Implementability**	**Adverse Impacts**	**Retain Yes/No**
Photo-Dehalogenation	Dehalogenates contaminants of concern, but VOCs are produced	Unknown	Unknown	Emerging	Requires H_2 gas or natural gas	Equipment not commercially available.	Requires further VOC treatment and scrubbing for HCI. A secondary treatment would be required to treat the dehalogenated VOCs.	No
Ozone-UV-GAC	Applicable to chlorinated and non-chlorinated volatile organics.	~98 percent destruction demonstrated. 99.9 percent may be Possible with the addition of more GAC.	Yes	Commercially available	Power, Acid Scrubbing Water	Equipment available. Compatible with the SVE unit.	Caustic Scrubbing. Spent GAC.	Yes
Adsorption/ Condensation (Purus)	Applicable to contaminants of concern.	Greater than 99 percent removal	Yes	Commercially available	Requires 208V and 100 Amp electrical power	Equipment available. Technology compatible with the SVE unit.	A VOC contaminated aqueous phase and potentially an organic liquid phase.	Yes

TABLE 5.2-1

PRELIMINARY TECHNOLOGY SCREENING SVE OFFGAS

	Effectiveness			Implementability				
Technology	**Applicability**	**Removal Efficiency**	**Potential to Meet Cleanup Goal**	**Technology Maturity**	**O&M Requirements**	**Implementability**	**Adverse Impacts**	**Retain Yes/No**
Condensation	Applicable to contaminants of concern	97.5 percent. GAC polishing is required to meet the cleanup goal.	Yes with GAC polishing	Commercially available	Requires electric power	Equipment commercially available. Compatible with the SVE unit.	GAC polishing required; A VOC contaminated aqueous phase and potentially an organic liquid phase.	Yes
Flameless Thermal Destruction	Applicable to chlorinated and non-chlorinated VOCs.	Greater than 99 percent Destruction	Yes	Commercially available	Supplemental fuel and/ or electrical power.	Equipment Available. Technology is compatible with the SVE unit as configured.	Caustic Scrubbing Required	Yes
Thermal Oxidation	Applicable to chlorinated and non-chlorinated volatile organics.	Greater than 99 percent Destruction	Yes	Commercially available	Requires a large volume of combustion fuel.	Equipment available. Technology is compatible with the SVE unit as configured.	Caustic scrubbing required.	Yes

TABLE 5.2-1

PRELIMINARY TECHNOLOGY SCREENING SVE OFFGAS

	Effectiveness			Implementability				
Technology	**Applicability**	**Removal Efficiency**	**Potential to Meet Cleanup Goal**	**Technology Maturity**	**O&M Requirements**	**Implementability**	**Adverse Impacts**	**Retain Yes/No**
Catalytic Oxidation	More applicable to streams containing > 1000 ppmv of organics	Greater than 99 percent Destruction	Yes	Commercially available	Requires a large volume of combustion fuel.	Equipment Available. Technology is compatible with the SVE unit as configured.	Caustic Scrubbing Required	Yes
Plasma Oxidation (High Energy Corona)	Applicable to chlorinated and non-chlorinated VOCs.	~ 99 percent PCE Destruction	Yes	Emerging (Pilot Tested)	90 kW required. Source of water may be needed for humidity control.	Full-scale systems have not been constructed or tested. The pilot system was designed and tested with a SVE system.	Caustic Scrubbing required.	Yes

6.0 DEVELOPMENT AND EVALUATION OF ALTERNATIVES

This section develops each of the retained technologies into alternatives and describes how each of these technologies would be incorporated with the existing SVE Pilot Unit. The development of alternatives includes identifying assumptions for design capacity, installation, and operations. These alternatives are then evaluated with respect to effectiveness, implementability and cost and a comparison of alternatives is performed. A description of the existing pilot unit and the GAC treatment system is provided to help define the integration of these treatment technologies. Advantages and disadvantages for integration with the SVE unit are also described. The following alternatives are identified for providing offgas treatment for the existing SVE Pilot Unit and the SPSH:

- Existing GAC treatment with offsite regeneration or disposal
- Ozone - UV - GAC
- Adsorption/Condensation (Purus)
- Condensation
- Flameless thermal oxidization
- Thermal oxidation
- Catalytic oxidation
- Plasma oxidation (High Energy Corona)

6.1 SUMMARY OF DESIGN CRITERIA

The design criteria for the SVE and SPSH systems have been discussed in detail in Section 4.0. The design criteria for developing the offgas treatment alternatives as summarized in Table 4.3-1 are presented below:

		Design	Maximum
Total Flow Rate (scfm)		300	500
Air Flow Rate (scfm)		150	500
Water Vapor Flow Rate	(scfm)	150	450
	(gpm)	2.5	2.5
Temperature (°F)		150	212
Pressure (inches Hg vacuum)		15	15
VOC Concentration (ppmv)		6,500	20,000
VOC removal rate (lbs/hr)		50	260
Total Water generated (gallons)		45,000	45,000
VOC Removal Efficiency			
Incinerators (percent)		99.99	99.99
Non-incinerators (percent)		95-99	>99

In addition, the alternatives need to be flexible, reliable, and portable to meet the needs of the pilot tests. Each of the alternatives need to incorporate as much as the existing SVE equipment as possible into the overall treatment system.

6.2 DEVELOPMENT AND SCREENING OF ALTERNATIVES

Each of the retained technologies are developed into offgas treatment alternatives based on the above design criteria and described in the following sections. The alternative descriptions include process flow diagrams, waste by-products, identification of new major equipment, modifications to the existing equipment, and utility requirements. Cost estimates are prepared for each alternative. Each of these alternatives is then evaluated with respect to effectiveness, implementability, and cost following the description of the alternative. A summary of this evaluation is shown on Table 6.2-1.

6.2.1 Existing SVE Pilot Unit with Off-site Regeneration or Disposal of GAC

The existing SVE Pilot Unit is housed in a portable semi-truck trailer that can be moved from various sites to conduct pilot tests of the SVE technology. The system is designed for a capacity of 300 scfm extraction capacity at 10 inches of Hg vacuum. A process flow diagram (PFD) of the system is shown in Figure 4.2-1. The extraction system uses two blowers in series to provide vacuum generation capabilities. Two blowers were used for this application to minimize the size of the vacuum system to fit inside the trailer. The offgas treatment system includes a knockout drum with a demister pad to remove entrained liquids from the extracted soil gas. The gas stream is then routed through High Efficiency Particulate Air (HEPA) filters to remove dust particles prior to treatment with GAC. There is a potential that radioactive isotopes attached to dust particles may be extracted with the soil gas from the abandoned disposal trench. This has the potential to make the GAC media a mixed waste and limit the disposal or regeneration options if it becomes contaminated. The HEPA filters provide pretreatment prior to the GAC units.

The two existing GAC units, 1,800 pounds each, are installed between the two extraction blowers. The GAC treatment system was designed to provide treatment of a contaminated gas stream with an inlet concentration of approximately 10 ppm v/v of total VOCs. The discharge after the second GAC unit is expected to be at or near non-detect concentrations. When organic breakthrough is observed between the two units, the lead unit will be taken off line. The GAC media will be removed and replaced with new media, and the original lead unit put back on line as the second unit with the other GAC unit now as the lead unit. Elevated concentrations greater than 10 ppm v/v of total chlorinated organics or 1 lb per day are expected for only short periods of time (a few hours to less than two days). Spent GAC removal and replacement were assumed to be minimal due to the restrictions of taking the

GAC off site for regeneration. This is based on existing philosophy that no GAC media have been taken off site for regeneration from RFP to date in association with environmental treatment and testing. The SVE system is designed to minimize and limit the potential of the GAC media from becoming a mixed waste material.

6.2.2 Ozone-UV-Granular Activated Carbon Alternative

The ozone-UV-GAC system consists of three separate units that include a gas phase photolytic reaction chamber, a mist air dispersion reactor and two trains of two GAC units as shown in Figure 6.2-1. The extracted soil gas would flow from the lead blower to the UV system outside the trailer. The extracted soil gas would enter the gas phase photolytic reactor chamber where the organics are oxidized by ozone-UV light. The gas stream is then scrubbed in the mist air dispersion reactor and transported to the GAC units. An ozone generation system would be required to support photolytic oxidation and the GAC regeneration step. The VOCs and ozone are adsorbed on the GAC prior to discharge. For this evaluation, two trains with two GAC units are assumed. Once the GAC is loaded and breakthrough is expected, the units are regenerated with ozone. VOCs with chlorine constituents will generate HCl that requires scrubbing. A caustic scrubbing system is included with the aqua reactor to provide offgas treatment for acid gas removal prior to discharge. Chlorine may ultimately reduce GAC adsorption capacity, but at the loading rate anticipated this is not expected to degrade the GAC to a level that requires it to be replaced during the life of the pilot study.

The extracted soil vapor gas stream passes through the ozone-UV-GAC unit (described earlier) which breaks down the contaminants into simpler compounds (H_2O, HCl, etc.). An on-site activated oxygen generator will provide the ozone for the system. A fan incorporated into the equipment will provide a net pressure drop of 0 in H_2O across the ozone-UV-GAC unit. The ozone-UV-GAC alternative will incorporate the SVE equipment into the overall system. The existing blowers and GAC vessels will be used. By-products from the system include the HEPA filters that remove radionuclides and other particulates from the flow stream. The regenerative GAC beds will return the purged gas stream to the beginning of the treatment unit. The only additional waste product is the spent caustic scrubbing solution that may require treatment prior to disposal.

Effectiveness

This alternative destroys 98% of CCl_4, PCE, and TCE on the first pass, and with recycling of the GAC adsorbate, the destruction efficiency approaches 99.9%. This alternative meets the requirements for the cleanup goal.

Implementability

The equipment for this alternative is commercially available and can be incorporated into the existing SVE. The GAC columns currently in service will be used in this alternative will be used in this alternative. This system has no limitations on VOC inlet concentration or water vapor content. This alternative requires approximately 14 kW of electrical power, caustic, water and replacement ultraviolet lamps. Wastes that will be generated include spent caustic, UV lamps, HEPA filters, and eventually exhausted carbon.

Cost

Capital and cost estimates for the ozone-UV-GAC alternative are shown in Table 6.2-2.

The cost of the ozone-UV-GAC unit is $285,000. With the supporting equipment required for this treatment alternative, the capital cost is approximately $1,250,000. Operating and maintenance costs per quarter are approximately $545,000.

6.2.3 Adsorption/Condensation Alternative Using PURUS Technology with Inlet Stream Cooling and Air Stripping of Extracted Groundwater

Under this alternative, the extracted soil vapor gas stream will first pass through a water knockout drum, to remove significant quantities of water vapor and droplets from the gas stream. The water will be pumped to an air stripper to remove entrained VOCs before pumping to a storage tank. The gas stream from the knockout drum will pass through HEPA filters to remove radionuclides and other particulates. A fin fan heat exchanger will cool the gas stream to below 120°F, the maximum inlet temperature for the PURUS module. The PURUS system would be installed after the lead blower as shown in Figure 6.2-2. A series of adsorption beds would remove the VOCs from the extracted soil gas. As one set of beds is treating, the other set is being regenerated. The regeneration process uses internal heating coils in the adsorption beds to evaluate the temperature of the adsorbent. A vacuum pump also lowers the operation pressure to help volatize the VOCs. The VOCs from the regeneration cycle are condensed in a two-stage condenser system operation. A mechanical refrigeration system provides coolant for the condensing step. Nitrogen gas is also used to purge the adsorption bed of VOCs prior to cycling back for treatment. The concentrated organic waste liquid is transferred to an on-site storage tank for eventual disposal. The pressure drop across the PURUS module is 16-20 in H_2O.

Modifications to the existing SVE unit include installation of a new water knockout drum before the HEPA filters, addition of an air stripper system to treat the groundwater from the knockout drum, addition of a fin fan heat exchanger prior to the Purus Module, and addition of the Purus Module itself. By-products include HEPA filters, condensate and the concentrated organic liquid. The concentrated organic liquid may require treatment as part of the disposal or may be recycled.

Effectiveness

This alternative would remove 95 to 99 percent of the CCl_4, and 99 percent of the PCE and TCE, the major contaminants in the gas stream. It removes both chlorinated and non-chlorinated compounds, and thus can meet the cleanup goal.

Implementability

The PURUS technology in this alternative is technologically mature and commercially available, and can readily be merged with the existing equipment. High VOC inlet concentrations can be accepted but the loading on the resins and desorption rate are affected. An air stream with 100 percent relative humidity can be accepted by this alternative. This alternative requires approximately 20 to 30 kW of electrical power and compressed nitrogen gas. The concentrated organic liquid would require off site treatment, recycle and/or disposal.

Cost

Capital and O&M cost estimates for the adsorption/condensation alternative are shown n Table 6.2-3.

The cost of the PURUS module is $300,000. With the supporting equipment required for this treatment alternative, the capital cost is approximately $1,190,000. Operating and maintenance costs per quarter are approximately 525,000.

6.2.4 Condensation/Refrigeration Alternative Using GAC Polishing and Air Stripping of Extracted Groundwater

The condensation/refrigeration system would replace the GAC unit as shown in Figure 6.2-3.

The extracted soil vapor gas stream will first pass through an air cooled condenser, to remove significant quantities of water vapor and entrained droplets from the gas stream. The water will be collected and pumped to an air stripper to remove dissolved VOCs and then pumped to a storage tank prior to disposal. The gas stream exiting the condenser at 40°F will pass through HEPA filters to remove radionuclides and other particulates. The condensing system will be installed after the lead blower, and the existing GAC units and second blower could be used in their existing configurations. The condenser, or potentially a series of condensers, would be skid mounted and installed adjacent to the trailer. A mechanical refrigeration system would provide cooling media to lower the soil gas temperature and promote condensing. Because the operating temperature of -30°F is well below the freezing point of water, dual heat exchanger units would be installed in parallel. The system will be automatically switched over to the second heat exchanger while the original system will be thawing out. All liquids will be transferred to a storage tank prior to trucking to a RFP treatment plant, or off site for treatment and disposal. The condensing system would have a VOC removal efficiency of 93 percent. The existing GAC units will provide the additional VOC removal requirement for a 99.9 percent removal efficiency of the system.

Modifications to the existing SVE unit include installation of a condenser prior to the HEPA filters to dehumidify the gas stream, addition of an air stripper system to treat the condensate, and addition of a refrigeration system with a recovery tank and a knockout drum prior to the existing GAC units. This alternative would generate a concentrated organic liquid and spent GAC that require further treatment recycle and/or disposal. Other by products requiring disposal include the treated condensate and HEPA filters.

<u>Effectiveness</u>

This alternative would remove 99.9% of CCl_4, PCE, and TCE, in addition to non-chlorinated and other chlorinated compounds in the gas stream. The GAC media is required to adsorb primarily CCl_4, which is difficult to condense. Condensation with GAC polishing can meet the cleanup goal.

Implementability

The equipment for this alternative is commercially available, and can use the existing GAC columns. This alternative has no limit on the VOC inlet concentration or water content of the air stream. The power requirement for this alternative is approximately 44 kW.

Cost

Capital and O&M cost estimates for the condensation/refrigeration alternative are shown in Table 6.2-4.

The cost of the condensation/refrigeration equipment is $176,000. With the supporting equipment required for this treatment alternative, the capital cost is approximately $840,000. Operating and maintenance costs per quarter are approximately $496,000.

6.2.5 Flameless Thermal Oxidation Alternative

The flameless thermal oxidizer would replace the existing GAC unit as shown in Figure 6.2-4. The contaminated air stream would pass through a condenser to remove most of the water vapor. The condensate water will be collected and treated by an air stripping system. The air stream would pass through HEPA filters to the flameless thermal oxidizer system. The oxidizer is a carbon steel shell with refractory lining and contains a packed bed matrix that supports the oxidation process. The oxidizer operates at approximately 1800°F. The integral electric preheater is used to heat the oxidizers ceramic bed on system startup and provide supplemental energy as needed to maintain the matrix at the operating temperature. The VOCs are oxidized to CO_2, H_2O, and HCl. The offgas from the oxidizer goes through a quench section for cooling. The offgas then goes to a scrubber where acid in the offgas are removed by caustic scrubbing. The caustic solution absorbs and neutralizes the HCl prior to discharge of the offgas stream to the atmosphere. The scrubber system would include a caustic supply tank, fresh water supply tank, mix tank for caustic dilution, scrubber with recirculation pump, and a spent caustic solution storage tank. No treatment of the spent scrubber solution is assumed at the pilot test site. The waste solution will be trucked to an existing facility at RFP or offsite for treatment and eventual disposal. The scrubber system could be installed on the oxidizer skid or on a separate skid. The scrubber system, caustic storage and mixing systems are assumed to be inside a secondary containment area or designed with double walled system and leak detection.

The existing lead blower in the SVE pilot unit should generate enough pressure without limiting the vacuum generation capability. The existing configuration of the two blowers operating in series will have to be modified as the thermal oxidizer and scrubber system are typically not designed for the vacuum pressures the SVE system can generate. There is also the potential that the existing blower may also need to be replaced with one blower. The flameless thermal oxidizer is assumed not to fit inside the trailer and would, therefore, be an external skid mounted unit. The organic treatment will be operated above atmospheric pressure. This does not meet the pilot test plan objective to complete all organic treatment under vacuum conditions to minimize potential leaks. This system can be designed, installed, and operated to provide the necessary treatment without having all the treatment system designed for vacuum operation. A propane storage tank will be used to provide fuel for startup and supplemental fuel for operation.

Modifications to the existing SVE unit include installation of a condenser prior to the HEPA filters to remove the water vapor, addition of an air stripper system to treat the condensate, and the oxidizer system with a caustic scrubber unit.

This alternative would generate a spent caustic and HEPA filters solution that may require further treatment prior to disposal.

Effectiveness

This alternative would remove 99.9 percent of the CCl_4, PCE and TCE in addition to nonchlorinated and other chlorinated compounds in the gas stream, and be able to meet the cleanup goal.

Implementability

The flameless thermal oxidation system is commercially available and has been proven to be effective at removing CCl_4. The existing equipment can be incorporated into this alternative. The oxidizer system requires approximately 45 to 76 kW power. This alternative has no limitations on inlet VOC concentrations.

Cost

Capital and O&M cost estimates for the flameless Thermal Oxidation Alternative are shown in Table 6.2-5. The cost of the flameless thermal oxidizer equipment is $380,000. Total capital costs are approximately $1,470,000. Operating and maintenance costs per quarter are approximately $575,000.

6.2.6 Thermal Oxidation Alternative

The thermal oxidation unit would be a skid mounted unit, nominally 6 feet wide by 10 feet long, replacing the existing GAC units as shown in Figure 6.2-5. The extracted soil gas stream would pass through a condenser operating at 40°F to remove the majority of the water vapor. The water would be collected and pumped to an air stripper for further treatment. The contaminated air stream would go through HEPA filters for radionuclide and particulate removal. After exiting the filters, the air stream enters the thermal oxidizer. A porous ceramic burner mixes the air stream and fuel before combustion in the thermal oxidizer. The oxidizer operating temperature ranges from 1600°F to 1800°F. The exhaust gas from the oxidizer contains HCl and requires further treatment before discharge to the atmosphere. The exhaust gas undergoes scrubbing with a caustic solution in the acid gas scrubber to remove greater than 99 percent of the acid. The caustic solution absorbs and neutralizes the HCl prior to discharge. The scrubber system would include a caustic supply tank, fresh water supply tank, mix tank for caustic dilution, scrubber with recirculation pump, and a spent caustic solution storage tank. No treatment of the spent scrubber solution is assumed at the pilot test site. The waste solution will be trucked to an existing facility at RFP or off site for treatment and eventual disposal. The scrubber system, caustic storage, and mixing systems are assumed to be designed with double walled system and leak detection.

The existing lead blower in the SVE pilot unit should generate enough pressure generation capacity without limiting the vacuum generation capability. The existing configuration of the two blowers operating in series will have to be modified as the oxidizer and scrubber system are typically not designed for the vacuum pressures the SVE system can generate. There is also the potential that the existing blowers may also need to be replaced with one blower. The organic treatment will be operated above atmospheric pressure. This system can be designed, installed, and operated to provide the necessary treatment without having all the treatment system designed for vacuum operation. A propane storage tank would be used to provide fuel for startup and supplemental fuel for operation.

Modifications to the existing SVE unit include installation of a condenser prior to the HEPA filters to remove the water vapor, addition of an air stripper system to treat the condensate, the oxidizer system with the caustic scrubber unit.

This alternative would generate a spent caustic solution that may require further treatment prior to disposal. The exhaust gas from this alternative contains less than 5 ppm NO_x.

Effectiveness

This alternative would remove greater than 99.9 percent of the CCl_4, PCE and TCE in addition to nonchlorinated and other chlorinated compounds in the gas stream and be able to meet the cleanup goal.

Implementability

The thermal oxidation system is commercially available and has been proven to be effective at removing CCl_4. The existing equipment can be incorporated into this alternative. This oxidizer system requires approximately 4 kW power. This alternative has a 5,000 to 6,000 ppm maximum VOC concentration limit on the inlet to the oxidizer. The oxidizer system operates more effectively with air streams at less than 80 percent relative humidity. More water vapor content increases the fuel and air consumption.

Cost

Capital and cost estimates for the Thermal Oxidation Alternative are shown in Table 6.2-6. The cost of the thermal oxidizer equipment is $50,000. Total capital costs are approximately $710,000. Operating and maintenance costs per quarter are approximately $500,000.

6.2.7 Catalytic Oxidation Alternative

The catalytic oxidation system would be similar to the thermal oxidation as shown in Figure 6.2-5. The extracted soil vapor stream would pass through a condenser to remove the majority of the water vapor. The condensate would be collected and pumped to an air stripper for further treatment. The air stream then goes through the HEPA filters and on to the catalytic oxidizer. The catalytic oxidizer operates at 600 to 900 °F. The air stream passes through the catalyst where an exothermic reaction takes place to convert the VOCs to CO_2, water, and HCl.

The exhaust gas from the oxidizer is further treated in the caustic scrubber to remove HCl. The caustic solution absorbs and neutralizes the HCl prior to discharge of the offgas stream to the atmosphere. The scrubber system would include a caustic supply tank, fresh water supply tank, mix tank for caustic dilution, scrubber with recirculation pump, and a spent caustic solution storage tank. No treatment of the spent scrubber solution is assumed at the pilot test site. The waste solution will be trucked to an existing facility at RFP or off site for treatment and eventual disposal. The scrubber system, caustic storage, and mixing systems are assumed to be inside a secondary containment area or designed with double walled system and leak detection.

The existing lead blower in the SVE pilot unit should generate enough pressure capacity without limiting the vacuum generation capability. The existing configuration of the two blowers operating in series will have to be modified as the oxidizer and scrubber system are typically not designed for the vacuum pressures the SVE system can generate. There is also the potential that the existing blowers may also need to be replaced with one blower. The organic treatment will be operated above atmospheric pressure. This system can be designed, installed, and operated to provide the necessary treatment without having all the treatment system designed for vacuum operation. A propane storage tank would be used to provide fuel for startup and supplemental fuel for operation.

Modifications to the existing SVE unit include installation of a condenser prior to the HEPA filters to remove the water vapor, addition of an air stripper system to treat the condensate, and the oxidizer system with the caustic scrubber unit.

This alternative would generate a spent caustic solution that may require further treatment prior to disposal. The exhaust gas would contain approximately 40 ppm of NO_x at 3 percent oxygen.

Effectiveness

This alternative would remove 99 percent of the CCl_4, PCE, and TCE in addition to nonchlorinated and other chlorinated compounds in the air stream and be able to meet the cleanup goals.

Implementability

The catalytic oxidation system is commercially available and has been proven on a full scale operation to be effective at removing CCl_4, PCE, and TCE. The existing equipment could be modified and incorporated into the overall treatment system. The oxidizer system requires only 8 kW power. The inlet air stream to the oxidizer has a limit of 2,500 ppm VOC without dilution air and can operate at 100 percent relative humidity in the air stream. For high inlet concentrations dilution air is required. At high relative humidities, additional fuel is required.

Cost

Capital and O&M cost estimates for the catalytic oxidation alternative are shown in Table 6.2-7. The cost of the catalytic unit is $85,000. Total capital costs are approximately $860,000. Operating and maintenance costs per quarter are approximately $515,000.

6.2.8 Plasma Oxidation (High Energy Corona) Alternative

The plasma oxidation or High Energy Corona System would replace the existing GAC unit as shown on Figure 6.2-6.

The extracted soil gas stream would pass through a condenser to remove most of the water vapor. The water from the condenser will be pumped to an air stripper to remove dissolved VOCs and treated water will be pumped to a storage tank. The gas stream from the condenser will pass through HEPA filters to remove radionuclides and other particulates. The gas stream then passes through the High Energy Corona reactors where the high voltage current ionizes the air forming a low temperature plasma. The plasma is expected to destroy a wide variety of organic compounds in air. Due to the VOCs in the SVE offgas, a caustic scrubber will be used to remove HCl from the gas stream as described in Section 6.1.5.

Modifications to the system include addition of the condenser before the HEPA filters, the air stripper system for treating water from the condenser, the High Energy Corona system, and the scrubber system (including a caustic supply tank, fresh water supply tank, mix tank for caustic dilution, scrubber with recirculation pump, and a spent caustic solution storage tank).

This alternative generates a spent caustic waste which may require treatment prior to disposal. The concentration of NO_x from the offgas is approximately 1 ppm.

<u>Effectiveness</u>

This alternative would remove 99 percent of the CCl_4, PCE and TCE in addition to nonchlorinated and other chlorinated compounds on the gas stream and be able to meet the cleanup goal.

Implementability

The plasma oxidation (HEC) system is commercially available, but has not been proven to be effective at removing CCl_4, PCE and TCE on a full scale level. The existing equipment can be incorporated into this alternative. The oxidizer system requires approximately 35 to 40 kW power. This alternative has been tested on air streams with VOC concentrations of up to 2,500 ppm and 100 percent relative humidity.

Cost

Capital and O&M cost estimates for the HEC are shown in Table 6.2-8. The cost of the plasma oxidization equipment is $60,000. Total capital costs are approximately $805,000. Operating and maintenance costs per quarter are approximately $510,000.

6.3 COMPARISON OF ALTERNATIVES

The alternatives described and evaluated in Section 6.2 are further evaluated by comparison to each other. Table 6.2-1 summarizes the effectiveness, implementability, and cost of each alternative and Table 6.3-1 compares how each alternative addresses key requirements.

The adsorption/condensation, catalytic oxidation, and High Energy Corona alternatives each have been reported to achieve 99 percent removal. Ozone-UV-GAC, condensation, flameless thermal, and thermal oxidation alternatives have been reported to achieve greater than 99 percent removal.

The thermal, catalytic and plasma oxidation alternatives, have limits on the VOC concentration in the inlet gas stream.

All of the alternatives will require a condensing step to remove the excess water vapor from the air stream. Most of the alternatives could operate at 100 percent relative humidity inlet conditions.

The oxidation alternatives will generate NO_x in their exhaust gas stream. NO_x emissions are regulated for this site.

The ozone-UV-GAC and oxidation alternatives will generate HCl in the exhaust gas. HCl is a hazardous air pollutant but is not regulated at this time. For this evaluation, a caustic scrubbing system capable of approximately 99 percent removal has been included as a reasonable control alternative in each of these alternatives. The scrubbing process will generate a spent caustic waste that may require treatment before disposal.

While all of the alternatives are commercially available, three of the technologies are considered proprietary and available from one source.

The thermal oxidation and High Energy Corona alternatives may be considered incinerators under RCRA (40 CFR Part 260.10) and therefore may be required to meet a 99.99 percent destruction removal efficiency.

The capital equipment costs for the ozone-UV-GAC, adsorption/condensation, and flameless thermal oxidation alternatives are all greater than $1 million. The capital equipment costs for the condensation, thermal, catalytic and plasma oxidation alternatives are all less than $1 million. Operating and maintenance costs for all alternatives are relatively close.

Therefore, the alternatives that can achieve the higher removal efficiencies at the lower cost will be retained. Condensation, thermal oxidation, catalytic oxidation, and plasma oxidation will be retained.

6.4 SUMMARY

As a result of this screening and evaluation process, four alternatives were retained for consideration as the offgas treatment system for future pilot tests. These four include condensation, thermal oxidation, catalytic oxidation, and plasma oxidation.

Thermal oxidation and plasma oxidation have the potential to be regulated under RCRA as an incinerator and may be required to meet 99.99 percent destruction removal efficiency. Therefore, it is recommended that these alternatives be removed from further consideration as these DREs are extremely stringent and may not be attainable during the pilot test.

The condensation alternative generates a concentrated organic liquid that also may be regulated as a hazardous waste under RCRA. This organic liquid would require offsite treatment/disposal, probably by incineration. The liquid could be disposed offsite for recycling depending on the classification of the waste. Therefore, it is recommended that this alternative be removed from further consideration.

TABLE 6.2-1

ALTERNATIVE EVALUATION FOR SVE OFFGAS

Alternative	Effectiveness	Implementability	Cost	Retain
Ozone-UV-GAC	Effective in meeting cleanup goal with recycling of GAC adsorbate. Greater than 99 percent VOC removal.	Commercially available and compatible with existing equipment. Generates spent caustic and spent carbon that will require disposal.	Capital: $1,250,000 O&M: $545,000	No
Adsorption/Condensation (PURUS)	Effective in meeting cleanup goal. 99 percent VOC removal.	Commercially available and compatible with existing equipment. Generates a concentrated organic liquid that will require further treatment/disposal or recycle.	Capital: $1,190,000 O&M: $525,000	No
Condensation	Effective in meeting cleanup goal. Greater than 99 percent VOC removal.	Commercially available and compatible with existing equipment. Generates a concentrated organic liquid that will require further treatment/disposal or recycle.	Capital: $840,000 O&M: $496,000	Yes
Flameless Thermal Oxidation	Effective in meeting cleanup goal. Greater than 99 percent VOC removal by destruction.	Commercially available and compatible with existing equipment.	Capital: $1,470,000 O&M: $575,000	No

TABLE 6.2-1
(Concluded)

Alternative	Effectiveness	Implementability	Cost	Retain
Thermal Oxidation	Effective in meeting cleanup goal. Greater than 99 percent VOC removal by destruction.	Commercially available and compatible with existing equipment.	Capital: $710,000 O&M: $500,000	Yes
Catalytic Oxidation	Effective in meeting cleanup goal. 99 percent VOC removal by destruction.	Commercially available, compatible with existing equipment, and proven technology on full scale application.	Capital: $860,000 O&M: $515,000	Yes
Plasma Oxidation (High Energy Corona)	Effective in meeting cleanup goal. 99 percent VOC removal (destruction) expected.	Commercially available but not proven in full scale application.	Capital: $805,000 O&M: $510,000	No

TABLE 6.2-2

CAPITAL/O&M COST ESTIMATE
OZONE-UV-GAC ALTERNATIVE

DIRECT COSTS

	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Ozone-UV-GAC Unit	1	$285,000	$285,000
(2)	pH metering pump and spent caustic neutralizer	1	$5,000	$5,000
(3)	Double Walled Caustic Storage Tank	1	$20,000	$20,000
(4)	Spent Caustic and Water Tanks	1	$20,000	$20,000
(6)	10,000 gal Water Tank	1	$10,000	$10,000
(7)	Spent Caustic and Soil Water Pumps	4	$1,000	$4,000
(8)	High Volume Condenser	1	$5,000	$5,000
(9)	Airstripper	1	$10,000	$10,000
(10)	Clean Water Storage	5	$20,000	$100,000
		SUBTOTAL MPE		$459,000
(11)	Miscellaneous Equipment	5% SUBTOTAL MPE		$22,950
	TOTAL MPE			$481,950
(12)	Installation of MPE	20% MPE		$96,390
(13)	Instrumentation and Controls	5% MPE		$24,098
(14)	Piping	10% MPE		$48,195
(15)	Electrical	10% MPE		$48,195
(16)	Site Preparation	5% MPE		$24,098
(17)	Utilities	5% MPE		$24,098
(18)	Buildings and Services	10% MPE		$48,195
	TOTAL DIRECT COSTS (DC)			$795,218

INDIRECT COSTS

(19)	Engineering, Supervision	5% DC	$39,761
(20)	Construction Expenses	5% DC	$39,761
(21)	Contractor's Overhead and Profit	10% DC	$79,522
	TOTAL INDIRECT COSTS (IC)		$159,044
	Contingency 30% of (DC + IC)		$286,278
	TOTAL CAPITAL COSTS		$1,240,540

TABLE 6.2-2
CAPITAL/O&M COST ESTIMATE
OZONE-UV-GAC ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	O&M for existing SVE unit	$385,000
2	Operations Labor (2 people @ $40/hr @ 2 hr/day @ 90 days)	$14,400
3	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
4	Maintenance 10% of MPE	$48,195
5	Environmental & Health Compliance Costs	$3,500
6	Utilities (14 kW x $.08/kW-hr x 2,160 hrs)	$2,420
7	Raw Materials	$14,000
8	Hazardous Waste Disposal	
9	Insurance 1% of Total Capital	$12,405
10	Property Taxes 4% of Total Capital	$49,622
11	SUBTOTAL (excluding contractor's fee)	$532,662
12	Contractor's Fee 15% of Labor & maintenance	$9,857
	TOTAL O & M	$542,519

TABLE 6.2-3

CAPITAL/OPERATION AND MAINTENANCE COST ESTIMATE
ADSORPTION/CONDENSATION (PURUS) ALTERNATIVE

DIRECT COSTS				
	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Adsorption/Condensation Unit (PURUS)	1	$300,000	$300,000
(2)	VOC Recovery Tank (Double Walled)	1	$20,000	$20,000
(3)	High Volume Condenser	1	$5,000	$5,000
(4)	Condensate and VOC pumps	4	$1,000	$4,000
(6)	Air Stripper	1	$10,000	$10,000
(7)	Condensate Storage Tanks	5	$20,000	$100,000
		SUBTOTAL MPE		$439,000
(8)	Miscellaneous Equipment	5% SUBTOTAL MPE		$21,950
		TOTAL MPE		$460,950
(9)	Installation of MPE	20% MPE		$92,190
(10)	Instrumentation and Controls	5% MPE		$23,048
(11)	Piping	10% MPE		$46,095
(12)	Electrical	10% MPE		$46,095
(13)	Site Preparation	5% MPE		$23,048
(14)	Utilities	5% MPE		$23,048
(15)	Buildings and Services	10% MPE		$46,095
		TOTAL DIRECT COSTS (DC)		$760,568
INDIRECT COSTS				
(16)	Engineering, Supervision	5% DC		$38,028
(17)	Construction Expenses	5% DC		$38,028
(18)	Contractor's Overhead and Profit	10% DC		$76,057
		TOTAL INDIRECT COSTS (IC)		$152,114
		Contingency 30% of (DC + IC)		$273,804
		TOTAL CAPITAL COSTS		$1,186,485

TABLE 6.2-3
CAPITAL/OPERATION AND MAINTENANCE COST ESTIMATE
ADSORPTION/CONDENSATION (PURUS) ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	O&M for existing SVE unit	$385,000
2	Operations Labor (2 people @ $40/hr @ 2 hr/day @ 90 days)	$14,400
3	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
4	Maintenance 10% of MPE	$46,095
5	Environmental & Health Compliance Costs	$3,500
6	Utilities (20.5 kW x $.08/kW-hr x 2160 hr)	$3,550
7	Raw Materials	$0
8	Hazardous Waste Disposal	-
9	Insurance 1% of Total Capital	$11,865
10	Property Taxes 4% of Total Capital	$47,459
11	SUBTOTAL (excluding contractor's fee)	$514,989
12	Contractor's Fee 15% of Labor & maintenance	$9,542
	TOTAL O & M	$524,532

TABLE 6.2-4

CAPITAL/O&M COST ESTIMATE
CONDENSATION ALTERNATIVE

DIRECT COSTS

	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Condensation Equipment	1	$176,000	$176,000
	Refrigeration Blower	1	INCL	
	Compressor	2	INCL	
	Air Cooled Condenser	1	INCL	
	Fin and Tube Coils	1	INCL	
(2)	10,000 gal. Double Walled Storage Tanks	5	$20,000	$100,000
(3)	Air Stripper	1	$10,000	$10,000
(4)	Storage Tank and Condensate Pumps	4	$1,000	$4,000
(5)	10,000 gal VOC Recovery Tank	1	$20,000	$20,000
		SUBTOTAL MPE		$310,000
(6)	Miscellaneous Equipment	5% SUBTOTAL MPE		$15,500
	TOTAL MPE			$325,500
(7)	Installation of MPE	20% MPE		$65,100
(8)	Instrumentation and Controls	5% MPE		$16,275
(9)	Piping	10% MPE		$32,550
(10)	Electrical	10% MPE		$32,550
(11)	Site Preparation	5% MPE		$16,275
(12)	Utilities	5% MPE		$16,275
(13)	Buildings and Services	10% MPE		$32,550
	TOTAL DIRECT COSTS (DC)			$537,075

INDIRECT COSTS

(19)	Engineering, Supervision	5% DC	$26,854
(20)	Construction Expenses	5% DC	$26,854
(21)	Contractor's Overhead and Profit	10% DC	$53,708
		TOTAL INDIRECT COSTS (IC)	$107,415
		Contingency 30% of (DC + IC)	$193,347
		TOTAL CAPITAL COSTS	$837,837

TABLE 6.2-4
CAPITAL/O&M COST ESTIMATE
CONDENSATION ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	O&M for existing SVE unit	$385,000
2	Operations Labor (2 people @ $40/hr @ 2 hr/day @ 90 days)	$14,400
3	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
4	Maintenance 10% of MPE	$32,550
5	Environmental & Health Compliance Costs	$3,500
6	Utilities (44 kW x $.08/kW-hr x 2,160 hrs)	$7,603
7	Raw Materials	$0
8	Hazardous Waste Disposal	-
9	Insurance 1% of Total Capital	$8,378
10	Property Taxes 4% of Total Capital	$33,513
11	SUBTOTAL (excluding contractor's fee)	$488,065
12	Contractor's Fee 15% of Labor & maintenance	$7,511
	TOTAL O & M	$495,575

TABLE 6.2-5

CAPITAL/O&M COST ESTIMATE
FLAMELESS THERMAL OXIDATION ALTERNATIVE

DIRECT COSTS

	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Condensation Equipment	1	$176,000	$176,000
	Refrigeration Blower	1	INCL	
	Compressor	2	INCL	
	Air Cooled Condenser	1	INCL	
	Fin and Tube Coils	1	INCL	
(2)	10,000 gal. Double Walled Storage Tanks	5	$20,000	$100,000
(3)	Air Stripper	1	$10,000	$10,000
(4)	Storage Tank and Soil Water Pumps	4	$1,000	$4,000
(5)	10,000 gal VOC Recovery Tank	1	$20,000	$20,000
		SUBTOTAL MPE		$310,000
(6)	Miscellaneous Equipment	5% SUBTOTAL MPE		$15,500
	TOTAL MPE			$325,500
(7)	Installation of MPE	20% MPE		$65,100
(8)	Instrumentation and Controls	5% MPE		$16,275
(9)	Piping	10% MPE		$32,550
(10)	Electrical	10% MPE		$32,550
(11)	Site Preparation	5% MPE		$16,275
(12)	Utilities	5% MPE		$16,275
(13)	Buildings and Services	10% MPE		$32,550
	TOTAL DIRECT COSTS (DC)			$537,075

INDIRECT COSTS

(19)	Engineering, Supervision	5% DC	$26,854
(20)	Construction Expenses	5% DC	$26,854
(21)	Contractor's Overhead and Profit	10% DC	$53,708
	TOTAL INDIRECT COSTS (IC)		$107,415
	Contingency 30% of (DC + IC)		$193,347
	TOTAL CAPITAL COSTS		$837,837

TABLE 6.2-5
CAPITAL/O&M COST ESTIMATE
FLAMELESS THERMAL OXIDATION ALTERNATIVE
(Concluded)

Item No.	Description		Quarterly O & M Estimate
1	O&M for existing SVE unit		$385,000
2	Operations Labor (2 people @ $40/hr @ 2 hr/day @ 90 days)		$14,400
3	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)		$3,120
4	Maintenance	10% of MPE	$32,550
5	Environmental & Health Compliance Costs		$3,500
6	Utilities (14 kW x $.08/kW-hr x 2,160 hrs)		$7,603
7	Raw Materials		$0
8	Hazardous Waste Disposal		-
9	Insurance	1% of Total Capital	$8,378
10	Property Taxes	4% of Total Capital	$33,513
11	SUBTOTAL (excluding contractor's fee)		$488,065
12	Contractor's Fee	15% of Labor & maintenance	$7,511
	TOTAL O & M		$495,575

TABLE 6.2-6

CAPITAL/O&M COST ESTIMATE
THERMAL OXIDIZER ALTERNATIVE

DIRECT COSTS

	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Thermal Oxidizer	1	$50,000	$50,000
(2)	Acid Scrubber	1	$30,000	$30,000
(3)	pH metering pump and post-scrubber neutralizer	1	$5,000	$5,000
(4)	Double Walled Caustic Storage Tank	1	$20,000	$20,000
(5)	Spent Caustic Storage Tank	1	$20,000	$20,000
(6)	Propane Storage Tank	1	$8,000	$8,000
(7)	Caustic and Concensate Pumps	4	$1,000	$4,000
(8)	Air Stripper	1	$10,000	$10,000
(9)	Condensate Storage Tanks	5	$20,000	$100,000
(10)	High Volume Condenser	1	$5,000	$5,000
(11)	10,000 gal Water Tank	1	$10,000	$10,000
		SUBTOTAL MPE		$262,000
(12)	Miscellaneous Equipment	5% SUBTOTAL MPE		$13,100
	TOTAL MPE			$275,100
(13)	Installation of MPE	20% MPE		$55,020
(14)	Instrumentation and Controls	5% MPE		$13,755
(15)	Piping	10% MPE		$27,510
(16)	Electrical	10% MPE		$27,510
(17)	Site Preparation	5% MPE		$13,755
(18)	Utilities	5% MPE		$13,755
(19)	Buildings and Services	10% MPE		$27,510
	TOTAL DIRECT COSTS (DC)			$453,915

INDIRECT COSTS

(19)	Engineering, Supervision	5% DC	$22,696
(20)	Construction Expenses	5% DC	$22,696
(21)	Contractor's Overhead and Profit	10% DC	$45,392
	TOTAL INDIRECT COSTS (IC)		$90,783
	Contingency 30% of (DC + IC)		$163,409
	TOTAL CAPITAL COSTS		$708,107

TABLE 6.2-6
CAPITAL/O&M COST ESTIMATE
THERMAL OXIDIZER ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	O&M for existing SVE unit	$385,000
2	Operations Labor (2 people @ $40/hr @ 2 hr/day @ 90 days)	$14,400
3	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
4	Maintenance 10% of MPE	$27,510
5	Environmental & Health Compliance Costs	$3,500
6	Utilities (4 kW x $.08/kW-hr x 2,160 hrs)	$691
7	Raw Materials (propane and caustic)	$24,300
8	Hazardous Waste Disposal	-
9	Insurance 1% of Total Capital	$7,081
10	Property Taxes 4% of Total Capital	$28,324
11	SUBTOTAL (excluding contractor's fee)	$493,926
12	Contractor's Fee 15% of Labor & maintenance	$6,755
	TOTAL O & M	$500,681

TABLE 6.2-7

CAPITAL/O&M COST ESTIMATE
CATALYTIC OXIDIZER ALTERNATIVE

DIRECT COSTS

	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Catalytic Oxidizer Unit	1	$85,000	$85,000
(2)	Acid Scrubber	1	$50,000	$50,000
(3)	Double Walled Caustic Storage Tank	1	$20,000	$20,000
(4)	Double Walled Spent Caustic Tank	1	$20,000	$20,000
(5)	Propane Storage Tank	1	$8,000	$8,000
(6)	pH metering pump and spent caustic neutralizer	1	$5,000	$5,000
(7)	High Volume Condenser	1	$5,000	$5,000
(8)	Condensate Storage Tanks	5	$20,000	$100,000
(9)	Caustic and Condensate Pumps	4	$1,000	$4,000
(10)	Air Stripper	1	$10,000	$10,000
(11)	10,000 gal Water Tank	1	$10,000	$10,000
		SUBTOTAL MPE		$317,000
(12)	Miscellaneous Equipment	5% SUBTOTAL MPE		$15,850
	TOTAL MPE			$332,850
(13)	Installation of MPE	20% MPE		$66,570
(14)	Instrumentation and Controls	5% MPE		$16,643
(15)	Piping	10% MPE		$33,285
(16)	Electrical	10% MPE		$33,285
(17)	Site Preparation	5% MPE		$16,643
(18)	Utilities	5% MPE		$16,643
(19)	Buildings and Services	10% MPE		$33,285
	TOTAL DIRECT COSTS (DC)			$549,203

INDIRECT COSTS

(19)	Engineering, Supervision	5% DC	$27,460
(20)	Construction Expenses	5% DC	$27,460
(21)	Contractor's Overhead and Profit	10% DC	$54,920
	TOTAL INDIRECT COSTS (IC)		$109,841
	Contingency 30% of (DC + IC)		$197,713
	TOTAL CAPITAL COSTS		$856,756

TABLE 6.2-7
CAPITAL/O&M COST ESTIMATE
CATALYTIC OXIDIZER ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	O&M for existing SVE unit	$385,000
2	Operations Labor (2 people @ $40/hr @ 2 hr/day @ 90 days)	$14,400
3	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
4	Maintenance 10% of MPE	$33,285
5	Environmental & Health Compliance Costs	$3,500
6	Utilities (8 kW x $.08/kW-hr x 2,160 hrs)	$1,382
7	Raw Materials (propane and caustic)	$24,300
8	Hazardous Waste Disposal	-
9	Insurance 1% of Total Capital	$8,568
10	Property Taxes 4% of Total Capital	$34,270
11	SUBTOTAL (excluding contractor's fee)	$507,825
12	Contractor's Fee 15% of Labor & maintenance	$7,621
	TOTAL O & M	$515,446

TABLE 6.2-8

CAPITAL/O&M COST ESTIMATE
HIGH ENERGY CORONA ALTERNATIVE

DIRECT COSTS

	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	High Energy Corona System	1	$60,000	$60,000
(2)	Acid Scrubber	1	$14,000	$14,000
(3)	Double Walled Caustic Storage Tank	1	$20,000	$20,000
(4)	Power supply, skid, and instrumentation	1	$50,000	$50,000
(5)	Double Walled Spent Caustic Storage Tank	1	$20,000	$20,000
(6)	High Volume Condenser	1	$5,000	$5,000
(7)	Caustic and Condensate Pumps	4	$1,000	$4,000
(8)	Condensate Storage Tanks	5	$20,000	$100,000
(9)	Air Stripper	1	$10,000	$10,000
(10)	pH meter and caustic neutralizer	1	$5,000	$5,000
(11)	10,000 gal Water Tank	1	$10,000	$10,000
		SUBTOTAL MPE		$298,000
(12)	Miscellaneous Equipment	5% SUBTOTAL MPE		$14,900
	TOTAL MPE			$312,900
(13)	Installation of MPE	20% MPE		$62,580
(14)	Instrumentation and Controls	5% MPE		$15,645
(15)	Piping	10% MPE		$31,290
(16)	Electrical	10% MPE		$31,290
(17)	Site Preparation	5% MPE		$15,645
(18)	Utilities	5% MPE		$15,645
(19)	Buildings and Services	10% MPE		$31,290
	TOTAL DIRECT COSTS (DC)			$516,285

INDIRECT COSTS

(19)	Engineering, Supervision	5% DC	$25,814
(20)	Construction Expenses	5% DC	$25,814
(21)	Contractor's Overhead and Profit	10% DC	$51,629
	TOTAL INDIRECT COSTS (IC)		$103,257
	Contingency 30% of (DC + IC)		$185,863
	TOTAL CAPITAL COSTS		$805,405

TABLE 6.2-8
CAPITAL/O&M COST ESTIMATE
HIGH ENERGY CORONA ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	O&M for existing SVE unit	$385,000
2	Operations Labor (2 people @ $40/hr @ 2 hr/day @ 90 days)	$14,400
3	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
4	Maintenance 10% of MPE	$31,290
5	Environmental & Health Compliance Costs	$3,500
6	Utilities (37.5 kW x $.08/kW-hr x 2,160 hrs)	$6,480
7	Raw Materials (caustic)	$16,800
8	Hazardous Waste Disposal	-
9	Insurance 1% of Total Capital	$8,054
10	Property Taxes 4% of Total Capital	$32,216
11	SUBTOTAL (excluding contractor's fee)	$500,860
12	Contractor's Fee 15% of Labor & maintenance	$7,322
	TOTAL O & M	$508,182

COST ASSUMPTIONS

The following summarizes the assumptions that were required in order to develop the cost tables for each of the offgas treatment alternatives:

Capital Cost Assumptions:

- A condenser is required to remove water vapor from the SVE gas stream in order to maintain the efficiency of the HEPA filters and to meet requirements of the offgas treatment technologies.

- The condensate stream with entrained VOCs will be treated. An air stripper system is included to remove VOCs from the condensate stream, and the treated water will be stored in five 10,000 gallon, double walled tanks. Two 10,000 gallon, double walled tanks from the existing SVE treatment system will be used to temporarily hold the condensate prior to treatment.

- An acid gas scrubber is incorporated in the offgas treatment system to remove HCl from the gas stream for those alternatives using oxidation/destruction technologies. The scrubber system would include double walled tanks for the caustic and the spent caustic and a single walled tank for water storage.

- Propane is assumed to be the fuel supplement for the thermal and catalytic oxidizer alternatives.

- A 10,000 gallon, double walled tank is also required for VOC storage for the adsorption/condensation and condensation alternatives that recover VOCs in liquid form.

Operations and Maintenance Cost Assumptions:

- The system will be operated 7 days per week, 24 hours per day for 90 days for Pilot Test No. 2.

- It is assumed that two operators are required on site during the entire test period. They will each devote two hours per day to the offgas treatment alternative. A supervisor and a site safety officer will each devote four hours per week to the offgas treatment alternative. Other health and safety costs are due to miscellaneous PPE.

- Electric utilities are costed for $0.08/kWh.

- Raw materials include propane and caustic. The thermal oxidation alternative was assumed to require twice as much propane as the catalytic oxidizer.

- Hazardous waste disposal costs were not included.

- The operations and maintenance costs for the existing SVE unit include: two operators for 22 hours per day (additional 2 hours per day included in labor cost for the offgas treatment alternative), a supervisor and site safety officer for 36 hours per week (additional 4 hours per week for each included in labor cost for the offgas treatment alternative), a sample/data manager for 40 hours per week, project manager for 10 hours per week, and additional maintenance, insurance, property tax costs and contractor's fees based on equipment costs for existing SVE unit.

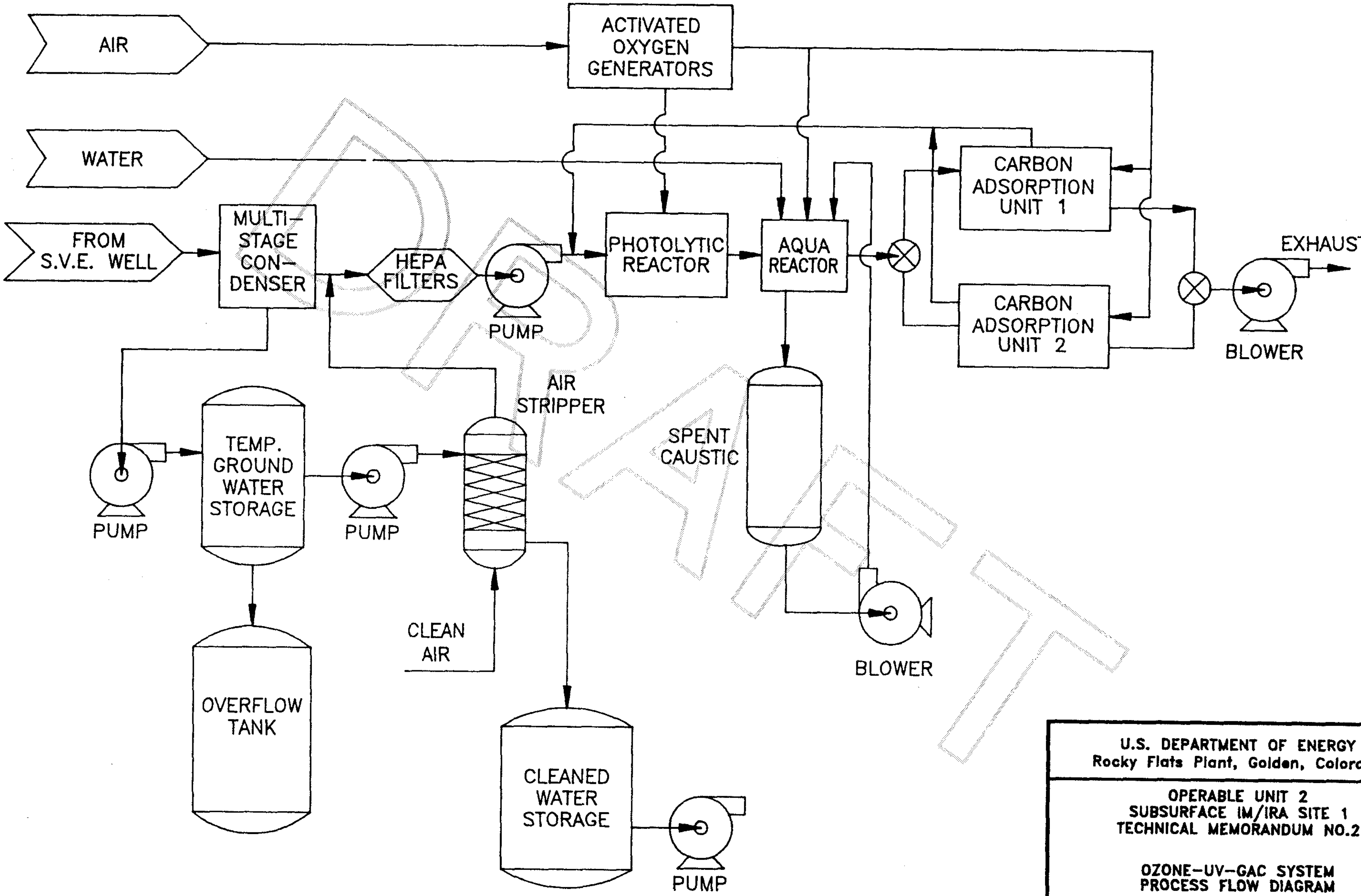
Other Assumptions:

- Permanent electrical power is assumed to be available. Therefore, no costs for operations and maintenance of diesel generators are included.

- Process water is available.

TABLE 6.3-1
ALTERNATIVE COMPARISON

	Carbon Tetrachloride removal efficiency	PCE Removal Efficiency	TCE Removal Efficiency	Maximum VOC limit	Maximum single contaminant conc.	Maximum water vapor	Maximum inlet temperature	NO_x production rate	HCL production rate	Power requirements	Delivery time
Adsorption/ Condensation (Purus)	95-99%	99%	99%	Higher conc. affects loading	Higher conc. affects loading	100% Relative Humidity (RH)	120 °F	none	0	20.5 kW Ave 27.6 kW Max	8 weeks
Ozone-UV-GAC	98% (99.9% w/polishing GAC)	98% (99.9% w/ polishing)	98% (polishing GAC)	no limit	no limit	100% RH, and droplets no problem		none	34.3 lb/hr	14 kW Ave	8 weeks
Condensation/ Refrigeration	99.9% w/polishing GAC			900,000 ppm v		100% of flow		none	0	44 kW Ave	16 weeks
High Energy Corona	99.5%			Testing up to 2,500 ppm v was successful. No higher tests.		100% RH at lest. Higher contents unknown.		1 ppm	34.3 lb/hr	35-40 kW Ave	40 weeks
Thermal Oxidizer	99.99%	99.99%	99.99%	5,000-6,000 ppm		80% RH Reheat before going to thermal unit. A larger water loading would require greater fuel and air consumption.	none	<5 ppm	34.3 lb/hr	4 Kw Ave	16 weeks
Catalytic Oxidizer	99.8%	99.5%	99.5%	2,500 ppm v with no dilution (no limit otherwise)	2,500 ppm v with no dilution (no limit otherwise)	100% RH, which would require supplemental fuel.	none	40 ppm @ 3% O_2	34.3 lb/hr	8 kW Ave	10 weeks
Flameless Thermal Oxidizer	99.9% at 1800 °F	99.99%	99.99%	No limit, except possible scrubber overload from Cl	No limit, except possible scrubber overload from Cl	80% RH, although a knockout drum for condensate will push this up to saturation.	none	<2 ppm	34.3 lb/hr	45 kW Ave 76 kW Max	14-20 weeks



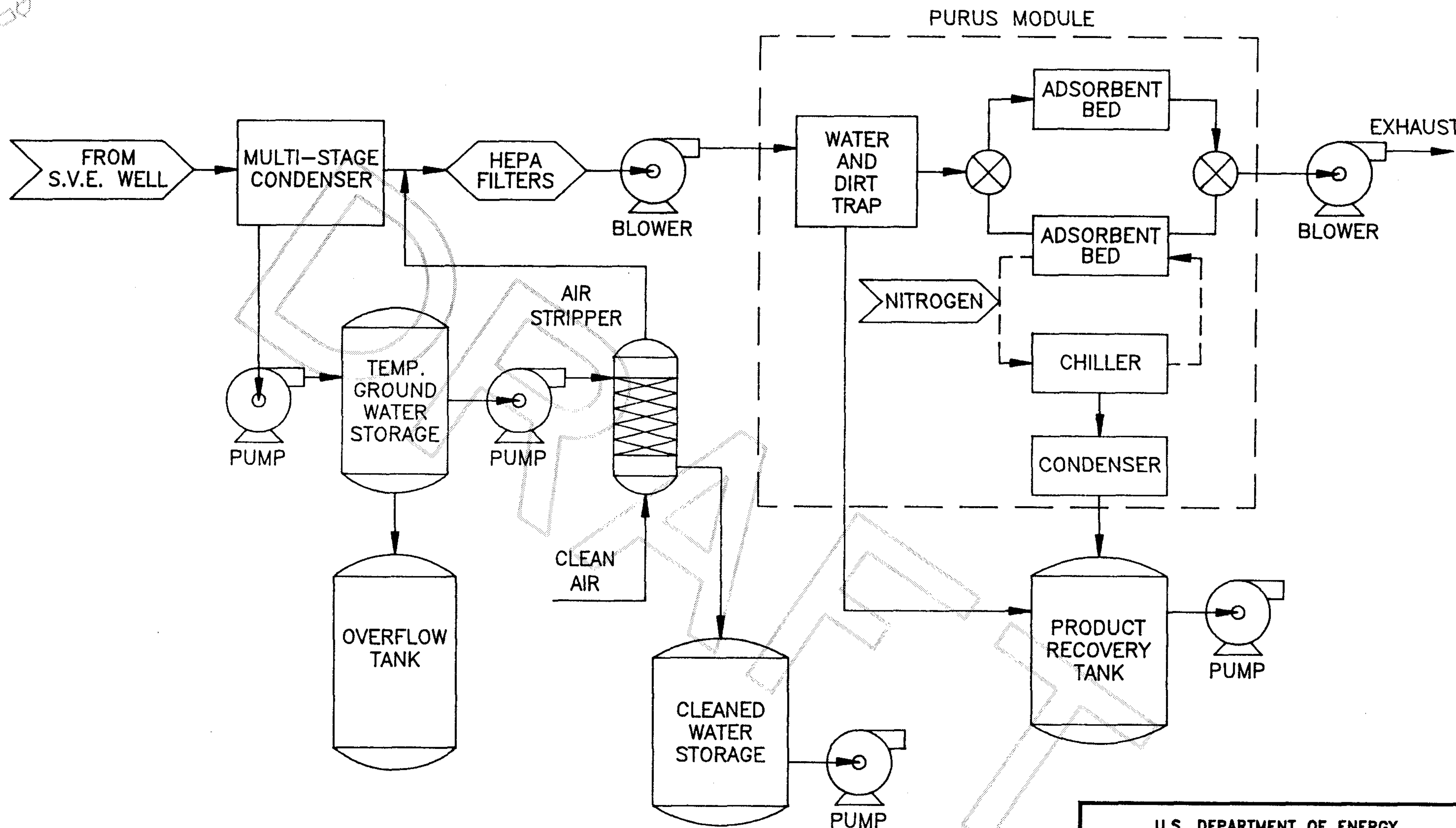
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2

OZONE-UV-GAC SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.2-1 MARCH 1994

4045014 1=1



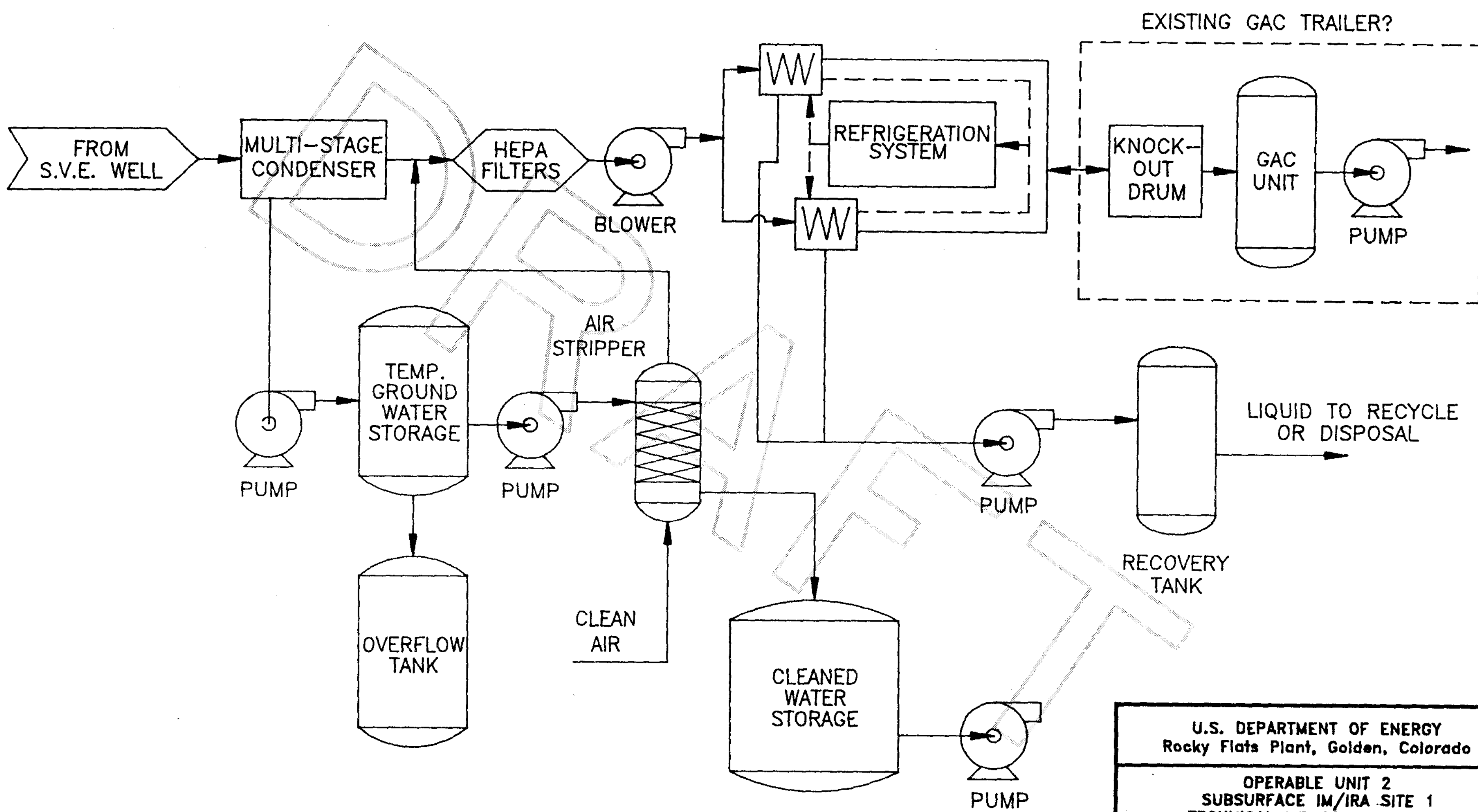
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2

PURICYCLE SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.1-2 MARCH 1994

4045010 1=1



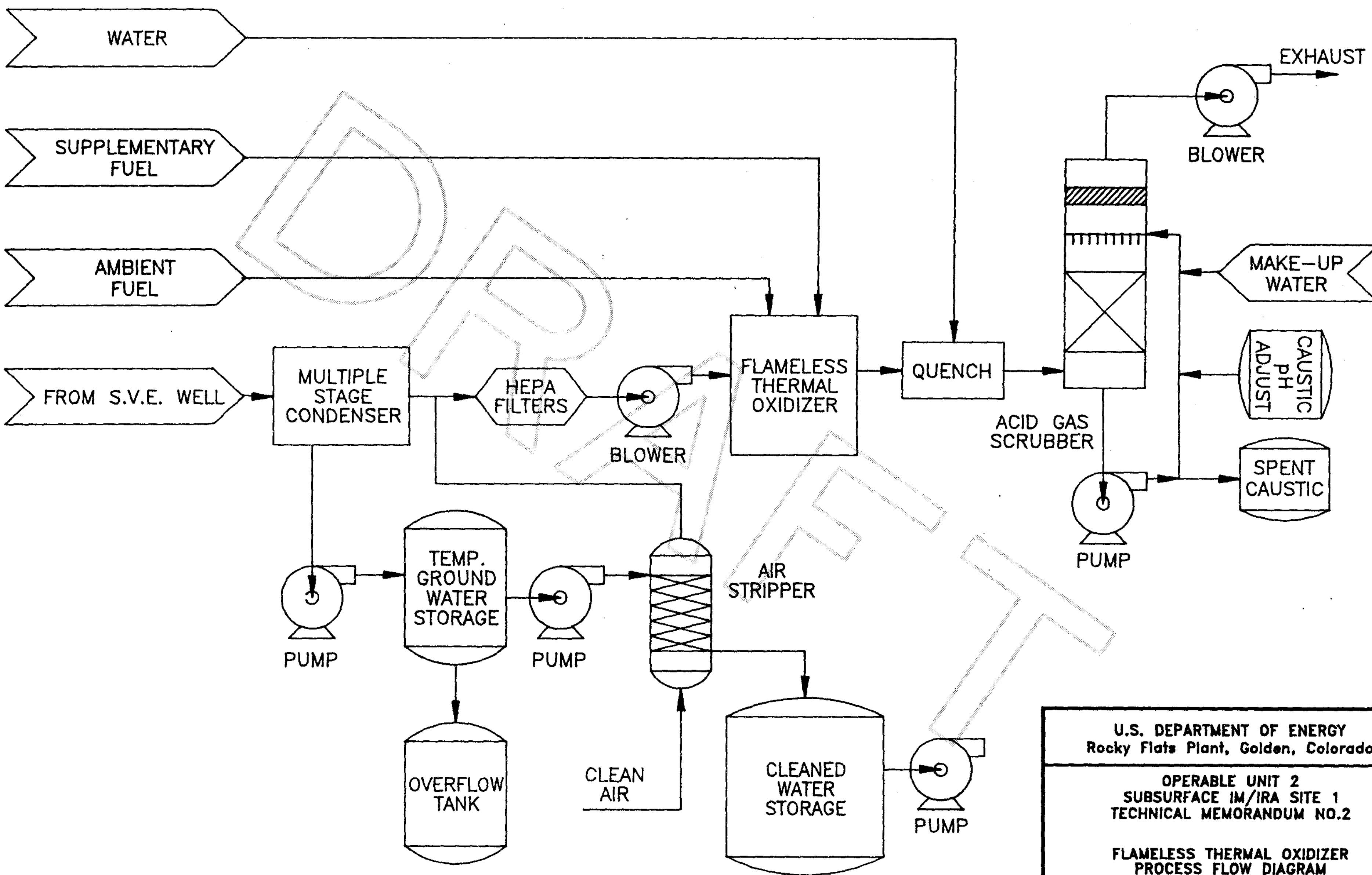
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2

CONDENSATION SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.2-3 MARCH 1994

4045009 1=1



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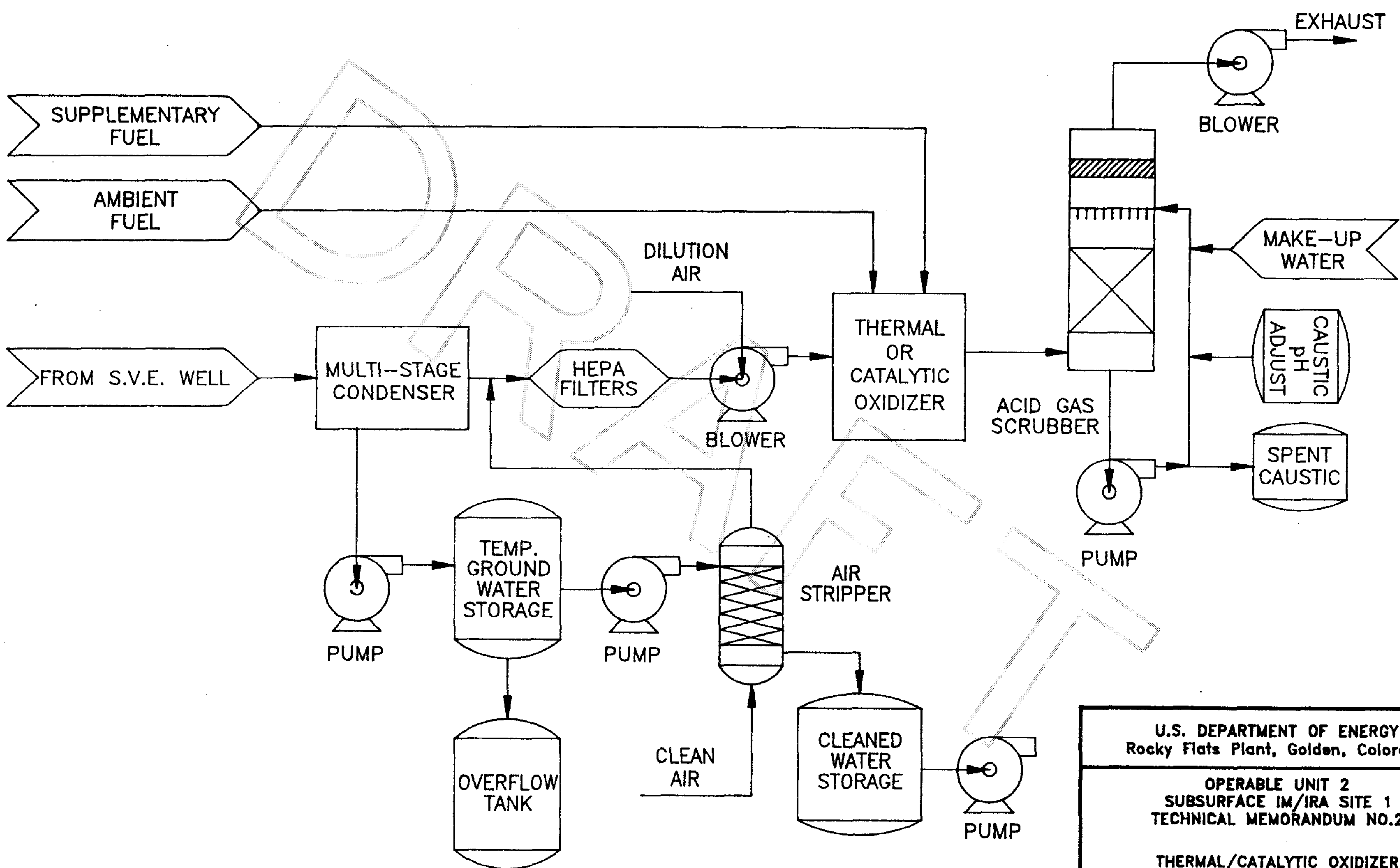
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2

FLAMELESS THERMAL OXIDIZER
PROCESS FLOW DIAGRAM

FIGURE 6.2-4 MARCH 1994

4045021 1=1



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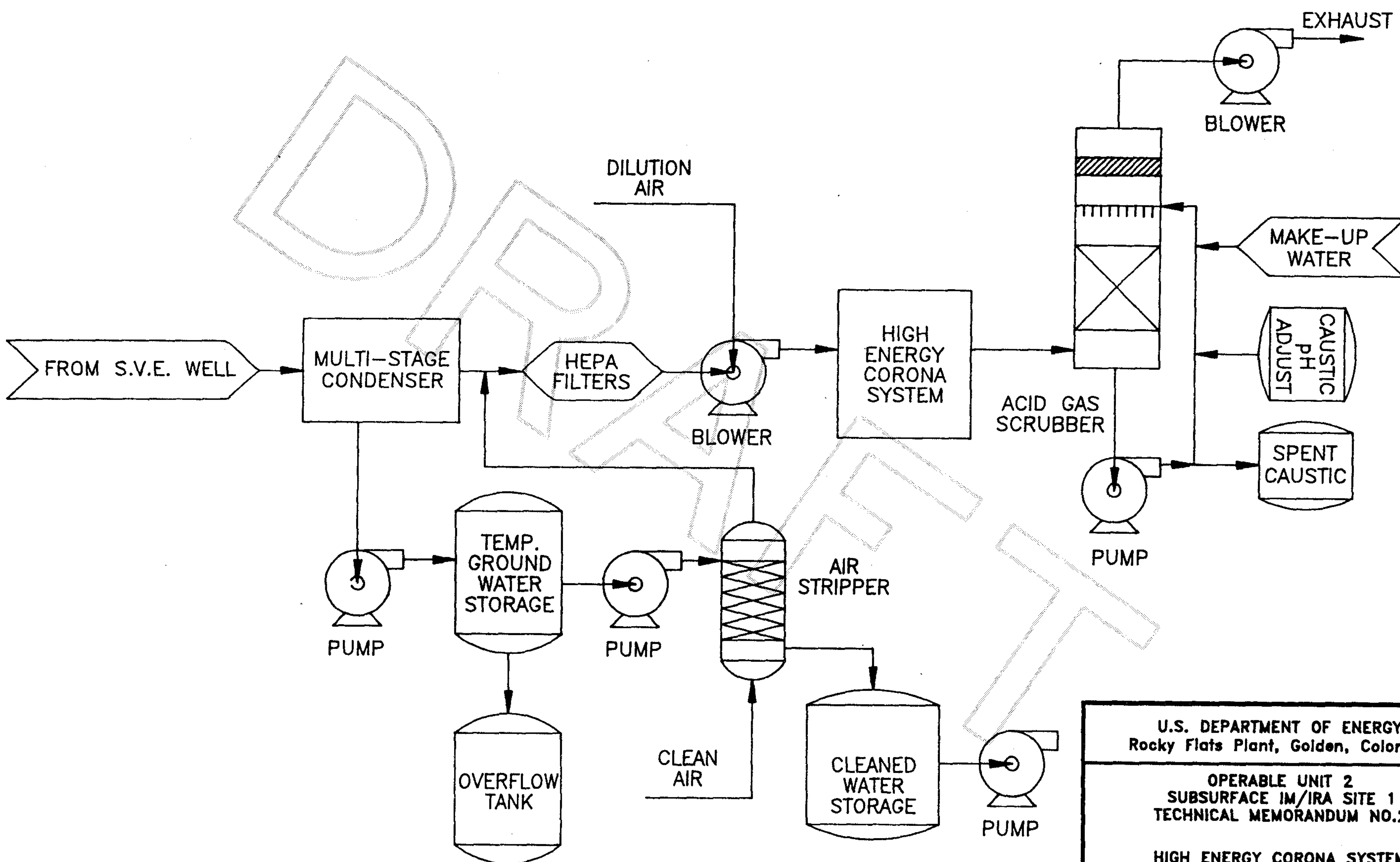
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2

THERMAL/CATALYTIC OXIDIZER
PROCESS FLOW DIAGRAM

FIGURE 6.1-5 MARCH 1994

4045007 1=1



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2

HIGH ENERGY CORONA SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.1-6 MARCH 1994

4045022 1-1

7.0 SUMMARY AND RECOMMENDATIONS

A screening and evaluation process provided a list of technologies to be further developed into alternatives to address the offgas treatment of VOCs from the SVE and SPSH technology pilot tests. Alternatives were developed and evaluated with respect to effectiveness, implementability, and cost as well as other site specific criteria.

The recommended alternative would be the catalytic oxidation alternative.

8.0 REFERENCES

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MDK

DRAFT A

TECHNICAL MEMORANDUM NO. 2

OU-2 SUBSURFACE IM/IRA

SOIL VAPOR EXTRACTION PILOT TEST

OFFGAS TREATMENT ALTERNATIVES EVALUATION

Rocky Flats Plant

(Operable Unit No. 2)

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden, Colorado

APRIL 1994

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TECHNICAL MEMORANDUM NO. 2
OU-2 SUBSURFACE IM/IRA
SOIL VAPOR EXTRACTION PILOT TEST
OFFGAS TREATMENT ALTERNATIVES EVALUATION

Rocky Flats Plant

(Operable Unit No. 2)

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden, Colorado

APRIL 1994

APPROVED BY:

Project Manager Environmental Restoration	Date

APPROVED BY:

Department/Group Manager Environmental Restoration	Date

APPROVED BY:

Quality Assurance Program Manager Environmental Restoration	Date

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LIST OF FIGURES

LIST OF ACRONYMS

APEN	Air Pollution Emission Notice
BGS	below ground surface
BH	borehole
BTU	British Thermal Unit
CDH	Colorado Department of Health
CFR	Code of Federal Regulations
CHC	chlorinated hydrocarbon
CMS/FS	Corrective Measure Study/Feasibility Study
DCA	dichloroethane
DCE	dichloroethene
DOE/RFO	Department of Energy/Rocky Flats Office
DRE	destruction removal efficiency
EPA	Environmental Protection Agency
GAC	granular activated carbon
HAP	hazardous air pollutant
HEPA	high efficiency particulate air
Hz	hertz
IHSS	Individual Hazardous Substance Site
IM/IRAP	Interim Measure/Interim Remedial Action Plan
kg	kilogram
kW	kilowatt
MACT	Maximum Achievable Control Technology
NAPL	non-aqueous phase liquid
NSR	New Source Review
O&M	Operation and Maintenance
OU-2	Operable Unit No. 2
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl (PCB)
PCE	tetrachloroethene
PFD	Process Flow Diagram
PID	photoionization detector
RACT	Reasonably Available Control Technology
RCRA	Resource Conservation and Recovery Act
RFA	Rocky Flats Alluvium
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFP	Rocky Flats Plant

SPSH	six-phase electrical soil heating
SVE	Soil Vapor Extraction
SVOC	semi-volatile organic compound
TCA	trichloroethane
TCE	trichloroethene
TM	Technical Memorandum
tpy	tons per year
TSD	treatment storage disposal
UHSV	upper hydrostratigraphic unit
UTL	Upper Threshold Limit
UV	ultraviolet
V	volt
VOC	Volatile Organic Compound
°F	Fahrenheit
μg	microgram

1.0 INTRODUCTION

The objective of Technical Memorandum No. 2 is to identify, evaluate, and select an appropriate offgas treatment technology for removal of VOCs from extracted soil gas. The primary criteria for this selection is that it meets performance standards for applications planned at OU-2, Pilot Test Sites No. 1 and No. 2.

The review addresses the existing SVE pilot unit and the additional system design requirements for thermally enhanced removal of organics using Six Phase Soil Heating (SPSH). Nonaqueous phase liquids identified in the subsurface soils from previous drilling programs have the potential to exceed the existing capacity of the offgas treatment system using Granular Activated Carbon (GAC).

An important secondary criteria is that the design meets the potential requirements of future offgas treatment applications for additional SVE programs at the Rocky Flats Plant (RFP) site. This requires the treatment system to be portable, to be able to efficiently treat a broad range of contaminant concentrations, and to be an established and proven technology at the scale being considered. The scope of identification, evaluation and selection of the treatment system is limited to technologies which can be retrofitted to the existing SVE pilot unit and operate in a self-contained manner.

1.1 PROJECT OVERVIEW

In September 1992, the Department of Energy/Rocky Flats Office (DOE/RFO) released a final Subsurface Interim Measure/Interim Remedial Action Plan (IM/IRAP) to investigate the removal of volatile organic compound (VOC) contamination from three areas within Operable Unit 2 (OU-2). Specifically, the SVE technology would be pilot tested within, or adjacent to, suspected VOC source areas in the 903 Pad, Mound and East Trenches. The Final Pilot Test Plan for the SVE technology was submitted to Colorado Department of Health (CDH) and Environmental Protection Agency (EPA) in January 1993, for Pilot Test Site No. 1 at the East Trenches (DOE 1993a).

In 1993, a pilot SVE unit using GAC for offgas treatment was fabricated off site. The unit was installed at Trench T-3, Individual Hazardous Substance Site (IHSS) 110 within OU-2. Pilot Test No. 1 is currently in progress. Pilot Test Site No. 2, scheduled for Spring 1995, will incorporate SPSH with the SVE technology.

In support of the pilot tests, this document is prepared to identify and evaluate the requirements for an alternative offgas treatment system. This system would be used with the existing SVE pilot unit and the SPSH system. Technical Memorandum (TM) No. 2 will identify and recommend an alternative offgas treatment system to be designed and purchased to support the SVE pilot tests. The potential sitewide application of the SVE system and alternative offgas treatment will also be evaluated.

1.2 MEMORANDUM OBJECTIVES

The purpose of this technical memorandum is to identify, evaluate, and recommend an offgas treatment system to support the SPSH and SVE technology pilot tests. The memorandum objectives include the following:

- Review and summarize the objectives for the IM/IRAP, Pilot Test Site No. 1, Pilot Test Site No. 2 and any additional pilot tests.
- Review and summarize the nature and extent of contamination at the pilot test site.
- Define the air emission standards or limits that the offgas treatment system would be required to achieve.

- Identify the design criteria for an offgas treatment system for the SVE and six-phase heating technologies.

- Evaluate various offgas treatment systems with respect to effectiveness, implementability and cost. The implementability criteria will include reliability, compatibility with the existing SVE unit, technology maturity, operation and maintenance requirements and adverse impacts.

- Identify by-products from the SVE, SPSH, and offgas treatment systems.

- Develop alternatives for offgas treatment.

- Identify required modifications to the existing SVE pilot system.

- Identify and recommend an offgas treatment alternative to support the pilot tests.

1.3 ORGANIZATION

TM No. 2 is organized into eight sections including references and appendixes:

- Section 1.0, Introduction, presents the project overview, the memorandum objectives and organization.

- Section 2.0, Evaluation Approach and Pilot Test Objectives, presents the approach for developing and evaluating the offgas treatment alternatives, IM/IRAP objectives and the pilot test objectives.

- Section 3.0, Pilot Test Site Subsurface Conditions, presents the nature and extent of contamination at the pilot test site, soil characteristics, and soil gas survey results.

- Section 4.0, Basis of Design for Offgas Treatment, presents the design and operating criteria for the SVE system, design criteria, and air emission limits for an offgas treatment system.

- Section 5.0, Technology Identification and Screening, presents offgas treatment technologies and an evaluation or screening of these technologies with respect to effectiveness and implementability.

- Section 6.0, Development and Evaluation of Alternatives, presents a summary of the design basis and alternatives for offgas treatment. This section will present cost estimates associated with these alternatives. This section will also present a brief summary of the report and recommends an offgas treatment alternative.

- Section 7.0 contains the references.

- The Appendix will contain capital and O&M costs for each alternative.

2.0 EVALUATION APPROACH AND PILOT TEST OBJECTIVES

The following sections identify the approach for developing and evaluating the offgas treatment alternatives and also presents the objectives of the Pilot Test Sites No. 1 and No. 2.

2.1 OFFGAS TREATMENT EVALUATION APPROACH

In order to begin to evaluate potential alternatives for offgas treatment for SVE and SPSH a design basis will be established. This design basis will include the site subsurface conditions, the design criteria for the existing SVE system and SPSH, regulatory requirements, site-specific criteria, and any waste restrictions. The subsurface conditions have been identified during the Phase I and Phase II RCRA Facility Investigation/Remedial Investigation (RFI/RI) and soil gas surveys performed as part of the SVE Pilot Test Site No. 1.

Potentially applicable offgas treatment technologies will be identified, described, and evaluated with respect to effectiveness and implementability. This evaluation will involve a review and screening of each technology and identification of retained technologies for evaluation and consideration as a treatment alternative.

Each of the retained technologies will be developed into alternatives. The alternatives will be conceptual level designs identifying all major pieces of equipment; power requirements; utilities needed; and generation, treatment, and disposal of by-products. The alternatives will be developed in conformance to the design criteria and to meet the treatment objectives. Capital and Operating and Maintenance (O&M) costs will be estimated for each alternative. The alternatives will then be evaluated with respect to effectiveness, implementability, and cost. A comparison of alternatives will be performed and a preferred alternative will be recommended for further design.

2.2 IM/IRAP OBJECTIVES

The IM/IRAP objective was to investigate the removal of VOC contamination in suspected subsurface areas at OU-2 using SVE technology. The IM/IRAP had identified three locations to test SVE technology: 903 Pad, Mound, and East Trenches. Pilot Test Sites No. 1 and No. 2 are discussed below.

2.3 PILOT TEST SITE NO. 1 OBJECTIVES

Pilot Test Site No. 1 for the SVE technology was selected based on soil gas survey data and known contamination at this particular site. The following are overall objectives of the pilot study:

- Assess the SVE technology for removal of VOCs in the Rocky Flats Alluvium (RFA) formation.
- Assess the SVE technology for removal of VOCs in sandstone with groundwater extraction.
- Assess active versus passive air injection.
- Incorporate information into the Corrective Measure Study/Feasibility Study (CMS/FS).
- Minimize adverse effects to environment during the pilot test.

2.4 PILOT TEST SITE NO. 2 OBJECTIVES

The purpose of the Pilot Test Site No. 2 for SPSH is to determine if this technology is a cost effective means of enhancing conventional SVE for removal of VOCs at the Rocky Flats site.

The following overall objectives of the pilot study are:

- Assess the ability of SPSH to accelerate the rate of removal of VOCs over conventional SVE at the Rocky Flats site.
- Assess the ability of SPSH to increase the extent of removal over conventional SVE of VOCs existing with inhibiting co-contaminants at the Rocky Flats site.
- To collect sufficient data to project economic feasibility and O&M reliability of additional applications of SPSH-SVE at other Rocky Flats sites.

3.0 PILOT TEST SITE SUBSURFACE CONDITIONS

The location for Pilot Test Sites No. 1 and No. 2 is Trench T-3 as shown on Figure 3.1-1, which is located north of Central Avenue, east of the inner fence, and south of South Walnut Creek. Trench T-3 was used from 1954 to 1963 for burial of sanitary sewage sludge contaminated with depleted uranium and plutonium in addition to flattened drums contaminated with depleted uranium. The nature and extent of contamination within subsurface soils and soil gas in the vicinity of Trench T-3 are discussed below.

3.1 SUBSURFACE SOILS

Three source boreholes, three plume characterization monitoring wells, one pilot borehole and seven SVE locations were drilled and sampled during Phase I, Phase II, and SVE investigations to characterize the vertical extent of contamination in Trench T-3 (10191, 02991, 12191, 21693, 22493, BH3987, BH4087, 24093, 24193, 24493, 24593, 24693, 24793, and 25093). The subsurface soil sample results from these boreholes and wells were used in the statistical detection frequency calculations (Table 3.1-1 and Figures 3.1-2 and 3.1-3).

<u>VOCs</u>

Seventeen VOCs were detected in subsurface soil samples collected within Trench T-3 (IHSS 110), as shown on Table 3.1-1. Some of these are suspected laboratory and field contaminants (see the OU-2 Phase II RFI/RI report [DOE 1993b] for further discussion); (acetone, toluene, methylene chloride, and 2-butanone). Free product was observed in borehole 10191 at a depth of 4.2 feet during drilling. Source borehole 10191 exhibited elevated levels of 1,1,1-trichloroethane (TCA), carbon tetrachloride (CCl_4), chloroform ($CHCl_3$), tetrachloroethene (PCE), and trichloroethene (TCE) in the samples collected above the initial water at the time of drilling. In general, the concentrations of the chlorinated hydrocarbons (CHCs) decreased with depth in the vadose zone in source borehole 10191.

TABLE 3.1-1

ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Volatile Organic Compounds (µg/kg)						
Acetone	NA	57	30	52.6%	1085 - 96,000	7,511
Toluene	NA	58	33	56.9%	5J - 7,600	465
Methylene chloride	NA	58	15	25.9%	45 - 20	8.8
2-Butanone	NA	58	9	15.5%	40J - 140	67.1
1,1,1-Trichloroethane	NA	58	9	15.5%	6 - 27,000	8047
Carbon tetrachloride	NA	58	19	32.8%	3J - 700,000	62,964
Chloroform	NA	58	17	29.3%	1J - 8800	536
Tetrachloroethene	NA	58	28	48.3%	1J - 13,000,000	1,037,989
Trichloroethene	NA	58	7	12.1%	1J - 120,000	18,303
1,1-Dichloroethene	NA	58	1	1.7%	9	9
1,2-Dichloroethane	NA	58	4	6.9%	6J - 15J	11.7
1,2-Dichloroethene	NA	58	1	1.7%	1J	1
2-Propenoic acid, 2-methyl	NA	1	1	100.0%	6J	6
Ethylbenzene	NA	58	1	1.7%	2J	2
Methyl methacrylate	NA	1	1	100.0%	6J	6
Styrene	NA	58	1	1.7%	2BJ	2
Total xylenes	NA	58	1	1.7%	7BJ	7

TABLE 3.1-1 (Continued)

ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Semivolatile Organic Compounds (µg/kg)						
Bis(2-ethylhexyl)phthalate	NA	21	20	95.2%	51J - 5500	503.8
Di-n-butyl phthalate	NA	21	1	4.8%	1300J	1300
Phenanthrene	NA	21	1	4.8%	2700J	2700
N-nitrosodiphenylamine	NA	21	1	4.8%	33J	33
2-Methylphenol	NA	21	1	4.8%	450	450
4-Methylphenol	NA	21	1	4.8%	2900	2900
Hexachlorobutadiene	NA	21	1	4.8%	170J	170
Hexachloroethane	NA	21	2	9.5%	370-1100	735
2-Methylnapthalene	NA	21	1	4.8%	8100D	8100
Naphthalene	NA	21	1	4.8%	2000	2000
Pesticides/PCBs (µg/kg)						
Aroclor-1254	NA	21	1	4.8%	6900D	6900

TABLE 3.1-1 (Concluded)

ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Radionuclides above background UTLs (pCi/g)(5)						
Americium-241	0.01	21	12	57.1%	0.01 - 0.5983	0.090
Plutonium-239	0.02	12	7	58.3%	0.02 - 1.1	0.209
Plutonium-239/240	0.02	9	8	88.9%	0.02855 - 3.12	0.47
Uranium-238	1.5	9	2	22.2%	1.611 - 26.37	14.0
Uranium-233,234	2.5	9	1	11.1%	14.35	14.35
Uranium-235	0.2	9	1	11.1%	0.7509	0.7509
Strontium-90	0.9	21	3	14.3%	0.9 - 1.1	1.0
Tritium (pCi/l)	366	21	1	4.8%	400	400.00

Locations: BH3987, BH4087, 02991, 10191, 12191, 21693, 22493, 24093, 24193, 24493, 24593, 24693, 24793, 25093

NA = not applicable
UTLs = upper tolerance limit
(1) Background concentrations do not exist and are not applicable for organic compounds.
(2) For radionuclides, the number of detections represent only detected concentrations exceeding the background 95% UTL.
(3) B and J qualifiers represent estimated result, D qualifier represents dilution result.
(4) The calculation for the mean concentration includes all J, D, and B qualified data.
(5) Only radionuclides detected above the background UTLs are listed. Number of detection, percent detections, concentration range, and mean concentration refer only to results exceeding background UTLs.

Below the water table, concentrations increased again, but to levels significantly lower than those seen in the vadose zone.

Semi-volatile Organic Compounds (SVOCs)

Ten SVOCs were detected in subsurface soil samples collected within Trench T-3, as shown on Table 3.1-1.

Pesticides/PCBs

Aroclor-1254, a polychlorinated biphenyl (PCB), was detected at an estimated concentration of 6,900D μg/kg in borehole 10191 from 1 out of 21 samples analyzed, taken at the depth of 4.2 to 8 feet, as shown on Table 3.1-1.

Radionuclides

Eight radionuclides detected at activities above the background UTLs are presented in Table 3.1-1. Elevated levels of radionuclides are concentrated in the 4.2- to 8-foot interval of borehole 10191 and generally decrease with depth, indicating the source of radionuclides to be within Trench T-3. Trench T-3 is estimated to be between 5 and 10 feet deep.

Summary

The subsurface soil analytical data collected from Trench T-3 indicate that it is a source of VOC contamination (1,1,1-TCA, CCl_4, $CHCl_3$, PCE, TCE, and 1,2-DCA) to the subsurface soil and potentially to upper hydrostratigraphic unit (UHSU) groundwater. The concentrations of CHCs decrease with depth down to the water table. There is minor contamination by polyaromatic hydrocarbons (PAHs) and other SVOCs. Elevated activities of Am-241, Pu-239, Pu-239/240, U-233,234, U-235, and U-238 are also present in Trench T-3.

3.2 SOIL GAS

Two soil gas surveys have been performed around Trench T-3 (IHSS 110). Both a shallow and a deeper survey have been carried out. The findings of the soil gas surveys are summarized below. The shallow (near surface less than a depth of five feet) soil gas survey analyses included the following VOCs:

- 1,1-dichloroethene (DCE)
- trans-1,2-dichloroethene (trans-1,2-DCE)
- cis-1,2-dichloroethene (cis-1,2-DCE)
- 1,1-dichloroethane (DCA)
- 1,2-DCA
- CCl_4
- PCE
- TCE
- Vinyl chloride
- Total VOCs

1,1-DCE, trans-1,2-DCE, cis-1,2-DCE, and 1,2-DCA were not detected in the soil vapor. 1,1-DCA was detected in 16 of 35 sampling locations and concentrations ranged from 40 to 1,900 µg/l. CCl_4 was detected in 18 of the 35 sampling locations with concentrations ranging from 0.36 to 111 µg/l. TCE was detected in 14 of the 35 sampling locations with concentrations ranging from 1.2 to 21 µg/l. PCE was detected in 22 of the 35 sampling locations with concentrations ranging from 0.11 to 410 µg/l. Vinyl chloride was detected in two sampling locations at concentrations less than 23 µg/l.

Review of the spatial distribution of the soil gas data in Trench T-3 indicates that CCl_4 may be found only in the west end of the trench (west of borehole 10191). The PCE soil gas plume is located in the west central part of Trench T-3 (located east of borehole 10191 and around the SVE wells and boreholes). The TCE soil gas plume is similar in location to the PCE plume. Two elevated total VOC concentration areas are observed in and around Trench T-3. One is located in the west central part of Trench T-3 (around the SVE wells and boreholes) and the second is located on the western end of Trench T-3 (west of borehole 10191).

The deeper soil gas survey (two surveys from depths of 5 and 10 feet) analytes are shown in Table 3.2-1 and include:

- 1,1-DCA
- CCl_4
- PCE
- TCE
- Total VOCs

Based on the evaluation of the soil gas obtained from the 5-foot sampling intervals, total VOCs appear to be concentrated on the western part of Trench T-3 (around borehole 10191). The CCl_4 soil vapor plume is located west of Trench T-3 boundary, while 1,1-DCA, PCE, and TCE are located at the western end of Trench T-3.

Review of the soil gas data obtained from a depth of 10 feet indicates that total VOCs, CCl_4, and PCE were observed at higher concentrations than at the 5-foot depth. 1,1-DCA was not detected in the 10-foot sample and TCE was detected at relatively low concentrations.

3.3 NONAQUEOUS PHASE LIQUID (NAPL)

A free phase NAPL, dark-brown in color, was observed in borehole 10191 (Phase II RFI/RI program) at a depth of approximately 4 feet and a residual NAPL was identified at approximately 6.5 to 7 feet during drilling operations. Borehole 10191 was drilled to a depth

TABLE 3.2-1

OU-2 SUBSURFACE IM/IRA DETAILED SOIL VAPOR SURVEY FIELD REPORT

Location Code	Survey Coordinates		Soil Gas Sample Number	Comment	Sample Depth (ft)	Soil Gas Laboratory Data (μg/L)				
	Easting	Northing				1-1,DCA	CCL_4	TCE	PCE	Total VOCs
111.1-13	2087375	749933	bh36vs01		5.0	0	0	1	0.7	1.7
111.1-14	2087347	749923	bh37vs01		5.0	0	0.47	24	1	25.47
111.1-15	2087319	749912	bh30vs01		5.0	0	11	770	21	802
111.1-16	2087291	749901	bh31vs01		5.0	0	19	514	31	564
111.1-17	2087264	749889	bh19vs01		5.0	14	93	1,023	274	1,404
111.1-18	2087235	749879	bh20vs01		5.0	12	3	2,740	1,670	4,425
111.1-19	2087207	749868	bh23vs02	field replicate	5.0	5.9	0.5	1,670	4,000	5,676.4
111.1-20	2087179	749858	bh24vs01		5.0	0	0.2	110	896	1,006.2
111.1-21	2087150	749849	bh25vs01		5.0	0	0	0.8	4.4	5.2
112-65	2085911	748788	bh40vs01		5.0	0	0.3	4.1	7.7	12.1
112-66	2085908	748814	bh39vs01		5.0	0	0.3	3.2	52	55.5
112-67	2085876	748801	bh38vs01		5.0	0	0	0.97	1.25	2.22
112-68	2085609	749135	bh61vs01		5.0	0	156	1.4	6.8	164.2
112-69	2085616	749035	bh60vs01		5.0	0	90	1.5	5.5	97

TABLE 3.2-1
(Concluded)

Location Code	Survey Coordinates		Soil Gas Sample Number	Comment	Sample Depth (ft)	Soil Gas Laboratory Data (μg/L)				
	Easting	Northing				1-1,DCA	CCL_4	TCE	PCE	Total VOCs
112-70	2085615	748975	bh59vs01		5.0	0	21	0.51	2.2	23.71
112-71	2085661	748957	bh58vs01		5.0	0	31.2	0.64	1.1	32.94
113-34	2086012	749539	bh01vs01		10.0	0	0	0	30	30
113-35	2086033	749569	bh03vs01		10.0	0	0	0	2.7	2.7
113-36	2086057	749563	bh04vs01		10.0	0	0.4	1.1	25	26.5
113-37	2086041	749606	bh05vs01		5.0	0	0	0	0.9	0.9
113-37	2086041	749606	bh05vs02		10.0	0	0	0	4.3	4.3
113-38	2086001	749594	bh02vs01		5.0	0	51	930	2,500	3,481
113-38	2086001	749594	bh02vs02		10.0	0	130	2,600	6,300	9,030
113-39	2086170	749587	bh11vs01		10.0	0	12	3,300	32,400	35,712
113-40	2086150	749588	bh09vs01		10.0	0	0.3	37	3,740	3,777.3
113-41	2086176	749558	bh12vs01		10.0	0	0	1.1	27	28.1
113-42	2086196	749561	bh14vs01		5.0	0	0	0	19	19
113-43	2086202	749586	bh13vs01		5.0	0	0	0	0.96	0.96
113-43	2086202	749586	bh13vs02		10.0	0	0	0	1	1
113-44	2086175	749619	bh10vs01		10.0	0	0	17	415	432

of 54 feet in three days. Analytical results obtained at this depth indicated the NAPL to contain the following chemicals: 1,1,1-TCA (13,000 μg/kg or ppb), CCl_4 (28,000 μg/kg), $CHCl_3$ (8,800 μg/kg), PCE (1,300,000 μg/kg), and TCE (120,000 μg/kg).

Based on the physical properties that control the migration of NAPLs, their free phase existence in or beneath Trench T-3 is unclear. It is possible that the free phase NAPL observed in borehole 10191 migrated vertically during the Phase II drilling operations or could be still trapped in Trench T-3.

At borehole 24793 in the SVE Pilot Test program, two VOC samples were collected because elevated organic readings were observed in the field by the photoionization detector (PID) and the discolored soil was observed in the borehole from the 7.7- to 8-foot sampling interval. The 7.7- to 8-foot core samples were described in the field to be a residual of a NAPL that discolored the soil. No free phase liquids were observed for these samples. Elevated PCE (1,090,000 μg/kg) and TCE (8,100 μg/kg) were detected in these samples. Upon encountering the NAPL in borehole 24793, drilling was stopped and the borehole was abandoned to prevent further contaminant migration.

3.4 SOIL CHARACTERISTICS

The surface soils at OU-2 are predominantly deep, well-drained loams, clay loams and very cobbly sandy loams with slow permeability. The Rocky Flats alluvium with the OU-2 area consist predominantly of beds and lenses of poorly to moderately sorted gravels and sands. A few lenses of clay and silt also occur. Results of geotechnical analyses are summarized in Table 3.4-1.

TABLE 3.4-1
OU-2 GEOTECHNICAL RESULTS
(ROCKY FLATS ALLUVIUM AND ARAPAHOE FORMATION)

New Site Number	Work Plan Site Number	Sample Depth (ft BGS)	Sample Strat.	Moisture Content (%)	Dry Density (pcf)	Gradation			Atterberg Limits			Perm.(1) (cm/sec)	Sample Description (USCS Symbol)
						Grave (%)	Sand (%)	Silt & Clay (%)	Liquid Limit (%)	Plastic Limit (%)	Plastic. Index (%)		
03091	30-91	43.7	Ka (No.1)	10.5	129.4	0	54	46	27	15	12	3.1E-9	Clayey Sand, Grey-Brown(SC)
03091	30-91	53.5	Ka (cs)	13.8	114.2	0	5	95	39	14	25	--	Lean Clay, Grey-Black(CL)
03591	35-91	26.5	Qrf	11.4	119.6	0	66	34	33	12	21	--	Clayey Sand, Light Red-Brown(SC)
03591	35-91	37.5	Ka (cs)	18.9	101.8	0	2	98	55	16	39	1.7E-8	Fat Clay, Grey-Brown(CH)
04491	44-91	19.8	Qrf	16.6	94.4	11	45	44	51	16	35	--	Clayey Sand, Orange-Brown(SC)
04491	44-91	26.8	Qrf	18.8	114.3	12	32	56	60	16	44	--	Sandy Fat Clay, Orange-Brown(CH)
05191	51-91	30.5	Qrf	13.3	116.5	0	50	50	40	14	26	1.9E-8	Clayey Sand, Orange-Brown(SC)
05191	51-91	48.5	Ka (cs)	15.1	110.7	0	40	60	36	15	21	--	Sandy Lean Clay, Light Grey(CL)
05191	51-91	50.5	Ka (cs)	20.6	106.9	0	11	89	42	15	27	--	Lean Clay, Grey(CL)
05291	52-91	13.3	Qrf	9.1	104.0	53	30	17	38	16	22	--	Clayey Gravel With Sand, Orange-Brown(GC)
05291	52-91	22.6	Qrf	12.5	119.2	14	56	30	47	16	31	--	Clayey Sand With Gravel, Orange-Brown(SC)
05291	52-91	29.6	Qrf	24.3	95.0	0	35	65	67	20	47	--	Sandy Fat Clay, Orange-Brown(CH)
05291	52-91	31.6	Qrf	18.4	109.4	0	49	51	40	15	25	--	Sandy Lean Clay, Orange-Brown(CL)
06191	61-91	1.6	Qrf	17.2	102.2	12	55	33	41	21	20	--	Clayey Sand, Orange(SC)
06191	61-91	10.7	Qrf	8.8	118.6	34	43	23	--	--	--	--	Clayey Sand With Gravel, Brown(SC)
06191	61-91	23.5	Qrf	5.5	114.8	48	40	12	--	--	--	--	Clayey Gravel With Sand, Orange-Brown(GC)
08591	5-91/BH419	40.7	Qrf	17.0	114.8	14	30	56	44	13	31	--	Sandy Lean Clay With Gravel, Olive-Brown(CL)
10291	BH3091	8.4	Qrf	5.2	--	51	35	14	--	--	--	--	Clayey Gravel With Sand, Orange-Brown(GC)
10291	BH3091	17.8	Ka (cs)	4.9	--	0	35	65	--	--	--	--	Sandy Lean Clay, Brown-Olive(CL)
10291	BH3091	21.8	Ka (cs)	11.5	119.5	0	50	50	30	13	17	--	Sandy Lean Clay, Grey-Brown(CL)
10291	BH3091	37.8	Ka (No.1)	10.3	121.5	0	81	19	28	11	17	3.7E-8	Clayey Sand, Orange-Grey(SC)
10291	BH3091	43.8	Ka (No.1)	14.0	115.3	0	52	48	NP	NP	NP	1.1E-8	Clayey Sand, Light Brown(SC)
10291	BH3091	47.8	Ka (No.1)	12.6	117.8	0	85	15	NP	NP	NP	--	Clayey Sand, Grey-Brown(SC)

TABLE 3.4-1
(concluded)

10291	BH3091	51.8	Ka (No.1)	14.2	119.5	0	31	69	36	13	23	5.0E-9	Sandy Lean Clay, Brown(CL)
10291	BH3091	57.8	Ka (No.1)	12.3	121.9	0	20	80	35	18	17		Lean Clay With Sand, Grey(CL)
10391	BH3191	35.8	Ka (No.1)	17.9	111.8	0	92	8	NP	NP	NP	1.1E-4	Sand With Clay, Grey(SP-SC)
10391	BH3191	61.8	Ka (No.1)	11.2	124.5	0	51	49	29	15	14	7.3E-8	Clayey Sand, Brown(SC)
10691	BH4291	29.0	Qrf	16.2	117.1	49	33	18	--	--	--	--	Clayey Gravel With Sand, Olive-Brown(GC)
10791	BH4391	28.4	Qrf	8.8	116.6	17	55	28	--	--	--	--	Clayey Sand With Gravel, Orange-Brown(SC)
10791	BH4391	33.8	Qrf	20.3	107.5	0	47	53	49	15	34	--	Sandy Lean Clay, Brown-Olive(CL)
10791	BH4391	37.3	Qrf	12.7	118.8	10	58	32	29	13	16	--	Clayey Sand, Orange-Brown(SC)
10891	BH4491	16.7	Qrf	15.4	105.7	15	52	33	45	17	28	--	Clayey Sand, Orange-Brown(SC)
10891	BH4491	25.8	Qrf	16.3	111.3	0	58	42	40	16	24	1.2E-8	Clayey Sand, Orange-Brown(SC)
20091	NA	28.1	Qrf	10.2	124.9	0	61	39	35	14	21	1.3E-7	Clayey Sand, Brown(SC)
20091	NA	40.7	Ka (No.1)	11.9	121.4	0	45	55	29	22	7	5.4E-8	Sandy Silty Clay, Brown(CL-ML)
20091	NA	49.6	Ka (No.1)	12.3	119.1	0	53	47	24	19	5	1.5E-7	Silty Clayey Sand, Brown(SC-SM)
20791	NA	15.3	Qrf	13.1	109.1	16	65	19	38	15	23	2.2E-8	Clayey Sand With Gravel, Brown(SC)
20791	NA	20.9	Qrf	8.0	147.2	56	36	8	34	16	18	--	Gravel With Clay and Sand, Brown(GP-GC)
20991	NA	42.8	Ka (No.1)	15.1	113.7	55	41	4	NP	NP	NP	1.1E-6	Gravel With Sand, Brown(GP)
20991	NA	56.8	Ka (No.1)	13.4	117.1	0	49	51	29	14	15	6.8E-8	Sandy Lean Clay, Brown(CL)
20991	NA	60.5	Ka (No.1)	--	--	42	51	7	--	--	--	--	Sand With Clay & Gravel, Yellow-Brown(SP-SC)

Notes :

BGS - Below Ground Surface	Ka - Arapahoe Formation	Perm. - Permeability
BH - Borehole	NA - Not Applicable	Plastic. Index - Plasticity Index
(cs) - Claystone	No. 1 - No. 1 Sandstone	Sample Strat. - Sample Stratigraphy
Qrf - Rocky Flats Alluvium	NP - Non-Plastic	

The symbol "--" indicates that the tests were not conducted on that sample.

(1) Permeability tests were conducted using the fixed-wall, falling-head method at 20 degrees C.

4.0 BASIS OF DESIGN FOR OFFGAS TREATMENT

The following sections detail the design criteria used in the development of the offgas treatment alternatives. These criteria include offgas treatment inlet and discharge conditions, requirements and limitations of the current SVE equipment and power supplies, regulatory requirements, and by product generation and disposal requirements.

4.1 SVE DESIGN CRITERIA FOR OFFGAS TREATMENT ALTERNATIVES

This section will define the design criteria for the existing SVE and SPSH systems. These criteria will be used to develop the design criteria for the offgas treatment alternatives. Additional data is currently being collected to confirm the design criteria established for the SVE system in its present configuration. This additional data may affect the offgas treatment final design criteria. Expanding the capability of the current SVE and offgas treatment system for higher contaminant concentrations and greater water vapor generated by SPSH requires review of the current system design and its limits.

4.1.1 SVE Criteria

The existing SVE system was designed to extract soil gas from an alluvium extraction well (AV1) or a sandstone extraction well (SV1). The soil gas stream is pulled through a demister in the knockout drum to remove entrained moisture. The stream then passes through High Efficiency Particulate Air (HEPA) filters to remove dust particulates that may be contaminated with radionuclides. Finally, the air stream passes through two vapor phase granular activated carbon GAC units (in series) for VOC removal. The treated air stream is then discharged to the atmosphere.

The SVE pilot unit is a transportable unit consisting of the following major pieces of equipment as shown on Figure 4.1-1:

- Knockout drum
- Liquid transfer pump
- HEPA filters (3)
- Blowers (2)
- GAC units (2)
- Air injection blower
- Groundwater storage tanks (2)

The design criteria for the system and each piece of equipment is summarized in Table 4.1-1.

The SVE pilot unit was designed to a National Electric Code (NEC) Class I Div. II electrical classification. The system is currently powered by a 125 kW transportable diesel generator. Electrical requirements are 460 volts/3 phase/60 Hz.

Current testing of the SVE technology will be under nine different sets of operating conditions to evaluate the system's performance and its limits.

Preliminary test data show the soil gas flow rate to the existing offgas treatment system averaging 11.4 cfm at 17.8% RH. Other parameters are listed in Table 4.1-2. The maximum values for each parameter are the design values. The soil gas stream is diluted prior to the offgas treatment. Make up air averages approximately 275 scfm.

Average concentrations of contaminants that have been seen in the soil gas stream (AV1) are as shown on Table 4.1-3.

TABLE 4.1-1

EXISTING SVE EQUIPMENT DESIGN CRITERIA

	Average	Maximum
System Airflow Rate	300 scfm @ 10 in Hg vacuum	600 scfm @ 0 to 2 in Hg vacuum
System Pressure/Vacuum	5 to 8 in Hg vacuum	10 in Hg vacuum
System Temperature		300°F
Blower B300	300 scfm	600 scfm 15 in Hg vacuum 100°F temp rise
Blower B500	300 scfm	500 scfm 18 in Hg 60°F temp rise
HEPA filters		
FL-200		500 scfm
FL-210		125 scfm
FL-220		500 scfm 10 in Hg operating vacuum
Knockout Drum	100 gal	150 gal 650 scfm 15 in Hg operating vacuum

TABLE 4.1-2

PILOT TEST NO. 1 INLET CONDITIONS OF EXTRACTED SOIL GAS AND MAKE UP AIR

Parameter	Minimum	Maximum	Average
Pressure (in. Hg vacuum)[1]	2	10	9.8
Soil Gas Flow Rate (scfm)	4	100	11.4
Soil Gas Relative Humidity (%)	5	100	17.8
Soil Gas Temperature (°F)	30	60	43.0
Makeup Air Flow Rate (scfm)	200	500	275
Makeup Air Relative Humidity (%)	8	100	10
Makeup Air Temperature (°F)	-10	110	60
Combined Flowrate (scfm)	300	600	310

1 The values for pressure measure the pressure drop, in inches of mercury, below one atmosphere, or 29.9 in Hg.

TABLE 4.1-3

AVERAGE VOC CONCENTRATIONS FROM COMPLETED PILOT TEST DATA

Analyte	AV1 (ppb)	Make Up Air (ppbv)	Blower 300 (ppbv)
	Average Concentration[1]		
CCl_4	577,500	.93	29,285
PCE	747,500	110.67	37,314
Total VOCs	1,402,250	116.60	70,632

[1] Based on currently unvalidated raw data from Pilot Test No. 1, run 2-3.

The system was designed to use two blowers in series. The blowers are located upstream and downstream from the GAC units. Recent pilot test data (Table 4.1-4.) have shown the discharge pressure and temperature from the first blower (B300) to be 5 to 7 in Hg vacuum and 90 to 120°F. Discharge conditions from the exhaust blower (B500) are 0.1 to 0.3 psig and 125 to 150°F. The discharge air flowrate from the system has been 300 to 350 scfm.

The current offgas treatment method is a vapor phase GAC system (D-400, D-410). The carbon steel vessels are four feet in diameter, approximately 7.5 feet tall, with a lined interior for corrosion protection. The vessels are ASME code stamped and rated for full vacuum. Basic design limits on the vessels are as follows in Table 4.1-5. Each column contains approximately 1,800 pounds of coconut based activated carbon (Westates VACarb or equivalent). Specifications for the carbon are also found in Table 4.1-5.

Table 4.1-6 shows maximum concentrations of each of the most prevalent VOCs and the corresponding removal rates for the contaminants.

The existing SVE and GAC system described above has the following limitations: the maximum system flow rate and pressure are approximately 600 scfm at 10 in Hg vacuum. The existing HEPA filters are rated at 10 in Hg vacuum maximum and would have to be replaced to achieve a higher vacuum operating pressure. The blowers are capable of 600 and 500 scfm maximum at low vacuum operating pressure (0 to 2 in Hg vacuum). The knockout drum has a limited capacity of 150 gallons.

4.1.2 SPSH Criteria

The SPSH will be tested at the same location as the Pilot Test Site No. 1, Trench T-3 (IHSS 110). The test will be comprised of three main testing periods:

TABLE 4.1-4

OPERATING CONDITIONS FROM COMPLETED PILOT TEST DATA

Location	P (in Hg)	ΔP (in Hg)	T (°F)	ΔT (°F)	RH (%)	Δ RH (%)	F (scfm)
Extraction Well (110)	-9.79	NA	23.8	NA	58.6	NA	11.43
Make Up Air (100)	-9.72	NA	24.0	NA	56.9	NA	272.86
Before HEPA Filter (200)	-10.58	-0.86	25.5	5.5	39.4	17.5	--
After HEPA Filter (201)	-10.83	-0.25	--	NA	--	NA	--
After Blower 300 (300)	-5.57	+5.26	101.5	76	3.13	36.3	--
After GAC 1 (400)	-3.79	+1.78	102[2]	0.5	--	NA	--
After GAC 2 (410)	-4.21	-0.42	86.3[2]	15.7	--	NA	--
After Blower 500 (500)	+.03	+4.24	138.3	52	--	NA	310.86

P = Pressure
ΔP = Pressure Change
T = Temperature
ΔT = Temperature Change
RH = Relative Humidity
ΔRH = Relative Humidity Change
F = Flow Rate

[1] Based on data from Pilot Test Nos. 2-3 and 3-2.
[2] Temperature measured in GAC unit prior to discharge.

TABLE 4.1-5

EXISTING GAC DESIGN CRITERIA

Air Flow Rate	300 scfm (average)	600 scfm (max)
Temperature	70°F (average)	200°F (max)
Pressure	8" Hg (average	10" Hg (max)
Pressure drop across units	--	1.5 psi (max)
Carbon Media Parameters:		
Size (U.S. Sieve)	4 x 8	
Type	Coconut Shell	
Hardness no. (min., wt.%)	97	
Ash (max., wt.%)	2	
Moisture (max. as packaged, wt.%)	2	
CCl_4 Activity (Min.)	62%	
Iodine No. (Min.)	1,000	
Retentivity (wt.%)	40	
Surface area (B.E.T)	1250 m^2/g	
Pore Volume	0.55 cc/g	
Mean particle diameter	3.4 mm	
Apparent density	29 lb./ft^3	

TABLE 4.1-6

ESTIMATED VOC REMOVAL RATES

PILOT TEST NO.	AVERAGE VOC CONCENTRATION (ppm/v)	AVERAGE VOC CONCENTRATION (ug/l)	AVERAGE FLOW RATE (scfm)	AVERAGE VOC REMOVAL FLOW RATE (lbs/hr)	HOURS OF OPERATION	LBS OF VOC REMOVED
1	1600	10872	6	0.24	4	1
2	1950	13250	13	0.64	55	35
3	700	4757	1	0.02	48	1
4	700	4757	7	0.12	48	6
5	1950	13250	16	0.79	16	13
6	2100	14270	18	0.96	16	15
7	800	5436	9	0.18	16	3
8	2100	14270	20	1.07	16	17
9	800	5436	11	0.22	16	4
					TOTAL LBS VOCS =	95

Baseline SVE Test Without Soil Heating

This test will be conducted over a few weeks to provide data on VOC concentrations in the extracted soil gas without heating. This data will be used to compare with the VOC concentrations in the extracted soil gas seen during heating as an indication of SPSH effectiveness. The requirements for the offgas treatment unit for this segment of the test will be similar to those for Pilot Test Site No. 1.

Six Phase Soil Heating

The heating part of this test will be run for approximately 45 days. Electrical power will be applied to the soil for heating during this time. Soil temperatures will increase to the boiling point of water over an estimated 10 day heat-up period. During this time, there will be some steam generated and extracted from the subsurface. The design conditions for this period are listed in Table 4.1-7 under the "Typical" operation column. When the bulk soil temperature has reached the boiling point of water, the offgas stream is expected to have a high water content. The design conditions for this case are listed in Table 4.1-7 under the "Maximum Steaming" column.

Cool-Down

After the soil heating has been discontinued, the soil will go through a cool-down period, lasting approximately 2 months. During this time, the offgas treatment unit will continue operation. The design conditions for this case are listed in Table 4.1-7 under the "Typical" operation column.

Power requirements for the SPSH are approximately 300 to 500 kW. Additional power will be required for the offgas treatment system.

TABLE 4.1-7

DESIGN CRITERIA FOR SPSH

	Typical	Maximum Steaming
Total flowrate (scfm)	300	500
Air flowrate (scfm)	150	50
Water vapor flowrate (scfm, gpm)	150 (0.8)	450 (2.5)
Temperature (°F)	150	212
Pressure (inches Hg vacuum)	15	15
VOC concentration (ppmv)	6,500	20,000
VOC removal rate (lbs/hr)	20 - 30	260
Total volume water generated (gallons)	45,000	45,000

4.1.3 SVE, SPSH, and Offgas Treatment Waste By-products

During normal operation of the SVE, SPSH, and offgas treatment systems, by-products are generated. The SPSH will be generating a large quantity of steam during operation. The first step in the soil vapor extraction process will be to condense the steam from the soil gas stream. This condensate will require storage and potential treatment prior to disposal. A total of approximately 45,000 gallons of condensate is estimated to be produced. The maximum flow rate is anticipated to be 2.5 to 3 gpm.

The condensate will contain varying amounts of VOCs, depending on the offgas treatment option selected, and may require treatment prior to release. The options for treatment and disposal of this condensate include the following:

- 881 Hillside water treatment unit (ultraviolet [UV] oxidation and ion exchange)
- OU-2 Field Treatment Unit (precipitation, membrane filtration, GAC)

Both of these options are existing treatment units with limited capacity and capabilities. Other options would involve addition of a new treatment system such as air stripping.

Other waste by-products of the existing SVE and GAC system include the used HEPA filters and the spent GAC. The used HEPA filters would be stored on site until further disposal disposition has been determined. HEPA filters will be part of the system used for the SPSH pilot test as well as additional pilot tests. Therefore, HEPA filters will be a waste by-product of all pilot tests. The spent GAC would be removed from the vessels and stored in drums on site. GAC depending on its chemical profile could be sent off site for regeneration. Other potential options include off-site disposal as a hazardous waste or on-site regeneration.

Some of the offgas treatment systems produce hydrogen chloride (HCl) in the offgas stream. The offgas is scrubbed with caustic solution to neutralize the acid prior to discharge. This further treatment produces a spent caustic solution which may require treatment prior to disposal or storage.

4.1.4 Other Criteria

In addition to the above design criteria, several other general criteria are important to the selection and design of the offgas treatment system. The future system should be portable to enable the complete treatment system to be moved to another site at RFP. The system should be capable of performing under future long term operations. The future offgas treatment should incorporate the existing SVE system and be amenable to retrofitting the existing system. The system should be self contained and require minimal utility hookups from the RFP site.

4.2 REGULATORY REQUIREMENTS

The following sections describe the regulatory requirements that may be applicable to the existing SVE system and potential offgas treatment alternatives used for the pilot tests. Since this is a CERCLA site, federal and state regulations may be potentially applicable to the offgas treatment systems being evaluated. Therefore, Resource Conservation and Recovery Act (RCRA) and state air emission regulations were reviewed for their applicability to the treatment alternatives. RCRA regulates the management, storage, treatment, and disposal of hazardous wastes. State air emission regulations regulate hazardous air pollutants.

4.2.1 Air Emission Requirements

Remediation of organic contaminated soils by the SVE technology can result in the release of VOC emissions to the atmosphere. The VOCs of concern for the pilot test sites No. 1 and

No. 2 are tetrachloroethylene (PCE), carbon tetrachloride (CCl_4), 1,1-dichloroethane (1,1-DCA), and trichloroethylene (TCE). These compounds are listed as hazardous air pollutants (HAPs) under the regulations of the CDH.

The regulatory requirements for the emission of these potential pollutants have been reviewed and are summarized below. Depending on estimated emission rates, these requirements could include initial reporting to CDH by submitting an Air Pollution Emission Notice (APEN). If the annual emission rate for each constituent is below the applicable reporting level, then an APEN is not required for that particular HAP. As defined by the CDH in Regulation 3 (August 30, 1993), the contaminants of concern for the pilot test sites No. 1 and No. 2 are categorized as HAPs and are assigned to Bins as defined by CDH which include Bin A (PCE and CCl_4), Bin B (1,1-DCA), and Bin C (TCE). The level at which emissions from the offgas treatment system would require reporting (submittal of a CDH APEN for each Bin) are:

- Bin A - 250 lbs/yr
- Bin B - 2500 lbs/yr
- Bin C - 5000 lbs/yr

Table 4.2-1 provides a comparison of the average VOC emission rate from the SVE system without offgas treatment to the maximum APEN reporting rate.

Table 4.2-2 provides a comparison of the average and maximum VOC emission rates from the SVE system without offgas treatment to the maximum reporting limit that triggers submittal of a CDH Construction Permit Application. Because Jefferson County is currently nonattainment for ozone, construction permits are required for VOC emissions greater than 2 tons per year. If the annual emission rate for each constituent is below the applicable Bin limit, then a Construction Permit is not required for that particular HAP. This table also

TABLE 4.2-1

COMPARISON OF EMISSIONS RATES TO CDH AIR POLLUTANT EMISSION NOTICE (APEN) CRITERIA

Contaminant	Average Emission Rate without Offgas Treatment (lbs/hr)	Average Emission Annual Rate without Offgas Treatement (lbs/hr)*	Max APEN Reporting Emission Rate (lbs/yr)
Bin A			
PCE	20.51	44,301.60	250
CCl_4	16.11	34,797.60	250
Bin B			
1,1 DCA	0.89	1,919.25	2,500
Bin C			
TCE	0.21	449.18	5,000

* Operating Scenario: 3 months (2,160 hours), 24 hours per day, 7 days per week

TABLE 4.2-2

COMPARISON OF EMISSIONS RATES TO CDH CONSTRUCTION PERMIT (C.P.) CRITERIA

Contaminant	Average Emission Rate without Offgas Treatment (lbs/hr)	Average Emission Annual Rate without Offgas Treatment (tons/yr)	Removal Efficiency to Remain Below C.P. App Rate (%)	Max Emission Rate without Offgas Treatment (lbs/hr)	Max Emission Annual Rate without Offgas Treatment (tons/yr)*	Removal Efficiency to Remain Below C.P. App Rate (%)	Max C.P. Emission Rate (tons/yr)
Bin A							
PCE	20.51	22.15	90.97%	27.19	29.37	93.19%	2
CCl_4	16.11	17.46	88.51%	21.36	23.07	91.33%	2
Bin B							
1,1 DCA	0.89	0.96	0.00%	1.18	1.27	0.00%	2
Bin C							
TCE	0.21	0.22	0.00%	0.28	0.30	0.00%	2
Total VOCs	38	41	95.09%	50	54	96.30%	2

* Operating Scenario: 3 months (2,160 hours), 24 hours per day, 7 days per weeks

provides an estimate of the removal efficiency that would need to be achieved in order to remain below the 2 tons per year total VOC emission rate that triggers the submittal of an application for a construction permit. Approximately 95 percent removal would provide sufficient control to achieve less than 2 tons per year being emitted.

Several offgas treatment technologies combust or oxidize the VOCs and produce CO_2, water, and HCl in the exhaust gas. HCl is also listed in the CDH regulations as a HAP and falls into Bin A.

In general, the VOCs and HCl are categorized as HAPs and have levels that trigger reporting but at this time have no emission standards that must be achieved. Therefore, only reasonably available control technology (RACT) can be applied. RACT allows the removal efficiency of the offgas treatment system to be one that is commonly achieved by similar equipment used in other applications. For the purpose of this evaluation of offgas treatment alternatives, RACT will apply and a removal efficiency of 95 percent or greater will be the criteria.

In addition to VOCs and HCl, some offgas treatment technologies and associated equipment produce nitrogen oxide (NO_x) emissions. NO_x emissions of 250 tons per year (tpy) designates a major source. Plant wide emissions of nitrogen oxides are well below the 250 tpy. Therefore, NO_x emissions associated with the offgas treatment system would need to exceed the requirements for criteria pollutants which NO_x is, before being required to file an APEN (greater than 2 tpy) or a CDH construction permit (greater than 10 tpy).

4.2.2 RCRA Requirements

RCRA regulates the management, storage, treatment, and disposal of hazardous waste. Hazardous waste is a subset of solid waste. Solid waste is defined by the RCRA statute as "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material including solid, liquid, semisolid, or contained gaseous material...." While uncontained gases are not regulated by RCRA, it is EPA's policy that offgases from the treatment of hazardous waste are regulated under RCRA under the derived-from rule. Thermal treatment units, depending on the type of unit and how it operates, can be regulated units under RCRA. The Code of Federal Regulations (CFR), Section 40, Part 264 contains the standards for regulated units. 40 CFR Part 266 contains standards for recycling units. Boilers and industrial furnaces are regulated under Part 266, Subpart H. Part 264, Subpart O contains the incinerator standards. Other types of thermal treatment units that do not qualify as either incinerators or boilers/industrial furnaces could be regulated as miscellaneous units under Part 264, Subpart X.

After review of Parts 264 and 266, it appears that thermal oxidation technology could be considered an incinerator under RCRA and subject to the performance standards. The other options, flameless thermal destruction, catalytic oxidation, and high energy corona could be considered miscellaneous units.

The incinerator standards in 40 CFR Part 264 Subpart O contain a section on performance standards (Section 264.343). For hazardous waste (except dioxin wastes), the incinerator must meet a destruction and removal efficiency (DRE) of 99.99 percent for each principal organic hazardous constituent. The miscellaneous unit standards have a general environmental performance standard in Section 264.601. This standard does not have specific DRE requirements but does, however, allow the requirements of Part 264, including Subpart O, to be applied if they are appropriate for the miscellaneous unit being permitted.

RCRA does regulate air emissions from process vents (40 CFR Part 264, Subpart AA) and equipment leaks (40 CFR Part 264, Subpart BB) at RCRA treatment, storage, disposal (TSDs) facilities. The process vent standards apply to process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, or air or steam stripping operations that manage hazardous waste with organic concentrations of at least 10 ppmv if these operations are conducted in units that are subject to RCRA permitting or hazardous waste recycling units. Closed-vent systems and control devices used to comply with the provisions of Subpart AA are regulated at 264.1033. Enclosed control devices (e.g., a vapor incinerator, boiler, or process heater) must reduce organic emissions vented to it by 95 weight percent or greater; achieve a total organic compound concentration of 20 ppmv; or provide a minimum residence time of 0.50 seconds at a minimum temperature of 760 degrees C.

It appears that RCRA may have applicability to some of the offgas treatment alternatives but to what degree would require a determination by the CDH RCRA division.

For the purpose of this evaluation of offgas treatment alternatives, it is assumed that the organic emissions should be reduced by 95 percent as stated above. This would be in agreement with the state requirement of RACT which has been estimated to be approximately 95 percent removal.

5.0 TECHNOLOGY IDENTIFICATION AND SCREENING

This section presents the potentially applicable technologies for treatment of VOCs in a gas stream. Each technology will be reviewed and discussed in general terms. The technologies will undergo a preliminary screening with respect to effectiveness and implementability. The technologies that pass the preliminary screening will be used to develop alternatives for the removal of VOCs from extracted soil gas.

5.1 TECHNOLOGY IDENTIFICATION AND SCREENING CRITERIA

Table 5.1-1 presents the list of potentially applicable technologies for treatment of VOCs in air streams. These technologies are discussed in the following sections.

TABLE 5.1-1

POTENTIALLY APPLICABLE TECHNOLOGIES

Granular Activated Carbon	Ozone-UV-Granular Activated Carbon
- Offsite Regeneration	Adsorption/Condensation (Purus)
- Offsite Disposal	Condensation/Refrigeration
- Onsite Regeneration	Flameless Thermal Oxidation
Membrane Separation	Thermal Oxidation
Biofiltration	Catalytic Oxidation
Chemical Reduction	High Energy Corona
Photo-dehalogenation	

The technologies were screened with respect to two major criteria: effectiveness and implementability. These criteria were defined as follows:

Effectiveness

Removal Efficiency - How effective is the technology at removing the contaminants of concern?

Implementability

1. Is the technology compatible with the existing SVE unit to minimize modifications to the process system?
2. Technology maturity for specific contaminant - At what level of development is the technology (e.g., emerging, commercially available, etc.)?
3. Operations - What items are necessary for operation and maintenance of the technology (e.g., incineration requires combustion fuel)?
4. Adverse impacts - If the technology is implemented, what wastes will be generated?

5.2 TECHNOLOGY DESCRIPTION AND PRELIMINARY SCREENING

5.2.1 Granular Activated Carbon (GAC)

The GAC technology is presently used for offgas treatment with the existing SVE pilot test unit. GAC media remove vapor-phase VOCs from gas streams by adsorption. The gas stream is passed through a packed column(s) of GAC media and the treated gas is discharged to the atmosphere. The VOC loading rates for the GAC media vary depending on the vapor phase constituents and their inlet concentrations. Once the GAC media are saturated and VOC breakthrough occurs, the GAC media are replaced. The media are typically regenerated or disposed of off site. Regenerated media can subsequently be reused as treatment media. However, VOC loading capacities for the regenerated GAC media are reduced through continued regeneration and recycling.

Effectiveness

GAC has been proven to be very effective at removing VOCs from gas streams, with removal efficiencies of greater than 99 percent. However, high concentrations and flow rates can quickly saturate the GAC media.

Implementability

The high water content flow stream expected with SPSH will require a condenser upstream of the GAC units. This condensate may require further treatment prior to disposal. The GAC technology will require offsite regeneration or disposal of spent carbon. The maximum operating inlet concentration to the GAC units is 5,000 ppmv, and shut-down occurs when concentrations exceed 10,000 ppmv. Higher concentrations of VOCs anticipated during SPSH would use more carbon, thereby generating larger quantities of spent carbon.

5.2.2 Membrane Separation

The membrane separation process is based on condensation and selective membrane permeability to VOCs versus oxygen, nitrogen, and other gases. The extracted gas is first compressed to 150 pounds per square inch (psig) and then cooled to approximately 35°F in a refrigerant cooled heat exchanger. Condensate is collected and removed. The uncondensed stream then enters the membrane unit and is separated into a VOC rich stream and a VOC depleted stream. The VOC rich stream is routed back to the soil gas stream prior to the compressor. The VOC depleted stream is then passed through GAC to remove the remaining VOCs. The membrane separation technology alone could achieve a 95 percent removal efficiency for VOCs. GAC treatment is added for increased VOC removal.

Effectiveness

This technology alone does have the potential to meet the minimum 95 percent removal efficiency. GAC polishing would have to be added to the treatment train to obtain a greater than 95 percent removal efficiency for VOCs.

Implementability

Membrane separation is commercially available and could be incorporated into the SVE unit at OU-2. Therefore, this technology will be retained for further consideration.

5.2.3 Biofiltration

Biofiltration was developed for the removal of organics from gas streams. The air stream passes through activated carbon media and adsorbs the VOCs. Microbes on the activated carbon media biologically reduce the VOCs to water and carbon dioxide. Biofiltration has not been demonstrated to process halogenated VOCs.

Effectiveness

This technology is not applicable to the contaminants of concern in the OU-2 air stream. On this basis, this technology will not be retained for consideration as part of a remedial action alternative.

5.2.4 Chemical Reduction

A gas-phase thermo-chemical reduction reaction of hydrogen with chlorinated organic compounds at elevated temperatures produces lighter, smaller hydrocarbons. The products are primarily HCl, hydrogen and methane. The reaction is enhanced by the presence of water. The waste stream is preheated to 302°F and then transferred to the reactor where it is heated to approximately 1650°F. The stream then passes through a scrubber where the HCl, heat, particulates, and water are removed. Ninety-five percent of the scrubber stream (primarily hydrogen and methane) is circulated back to the reactor. The remaining 5 percent is used for fuel for preheating the waste. Chemical reduction can not process streams containing oxygen.

Effectiveness

This technology is not effective for treatment of air streams containing oxygen. Therefore, chemical reduction will not be retained for further consideration.

5.2.5 Photo-dehalogenation

The process converts volatile halogenated compounds to less halogenated compounds or fully dehalogenated compounds by initiating reactions in a reducing atmosphere with ultraviolet light. The process inputs are hydrogen or natural gas, heat, and ultraviolet light. The primary products are dehalogenated organics and HCl. Therefore, a caustic scrubber will be needed to remove the HCl prior to venting, and a secondary treatment will be needed to process the dehalogenated volatiles.

Effectiveness

This technology is applicable for reducing the VOCs in the OU-2 air stream, although secondary VOC treatment would be required. The technology is emerging, so removal efficiencies are unknown.

Implementability

Equipment for this technology is not readily available.

Based on both effectiveness and implementability, this technology will not be retained.

5.2.6 Ozone-UV-Granular Activated Carbon (GAC)

The ozone-UV-GAC system is comprised of three unit processes, including a gas phase photolytic reactor chamber, a mist air dispersion reactor, and two GAC adsorption beds. The airstream first enters the photolytic reaction chamber, where the VOCs are oxidized in the presence of activated oxygen (ozone and hydrogen peroxide) and ultraviolet light. The mist air dispersion reactor ensures the minimum humidity level, further oxidizes the contaminants via sparging with the activated oxygen, and scrubs out HCl and Cl_2 which are by-products of the photolytic and aqua reactors. Finally, the air stream passes through the GAC bed which adsorbs any remaining contaminants. Dual GAC units are installed to provide treatment while one bed is being regenerated. The off-line GAC bed undergoes regeneration, where the GAC column is heated and flushed to desorb the contaminants. This desorbed gas stream is cycled back into the photolytic reactor inlet and reprocessed.

Effectiveness

This technology, with a destruction removal efficiency (DRE) of greater than 99 percent, is effective in treating the contaminants of concern in the OU-2 air stream.

Implementability

Although this is a proprietary technology through a single vendor, it is commercially available and compatible with the existing SVE unit. The system design would incorporate the existing GAC beds with some piping modifications, and would require an upstream condenser to remove the majority of the steam extracted from the ground. To support the system, an ozone generator and caustic are required. Waste streams include the spent caustic and the condensed offgas water.

This technology will be retained for further consideration.

5.2.7 Adsorption/Condensation (Purus)

This process is based upon VOC adsorption, bed regeneration, and VOC condensation and collection. The gas stream is passed through a packed bed of proprietary synthetic resin which removes VOCs. Once the bed is loaded, the offgas is diverted to a fresh bed. The loaded bed is regenerated by heating and flushing with nitrogen. The VOCs are then condensed and transferred to a storage tank from the flush gas. VOC removal is greater than 99 percent.

Effectiveness

This technology provides a greater than 99 percent removal efficiency for the contaminants of concern in the OU-2 air stream.

Implementability

The equipment is compatible with the existing SVE unit and readily available. The system requires nitrogen gas and an upstream condenser, and waste streams would include the condensed water and the recovered VOCs.

Therefore, this technology will be retained for consideration as part of a remedial action alternative.

5.2.8 Condensation/Refrigeration

The stream is passed through series of heat exchanger(s) to cool the gas and condense water and VOCs from the extracted soil gas stream. The cooling process can be accomplished in several steps and can use a combination of air heat exchangers, water heat exchangers, and refrigeration units. The treated stream will require a secondary treatment to remove the residual VOCs (e.g., GAC, catalytic oxidation, etc.).

<u>Effectiveness</u>

This technology is applicable for treatment of the contaminants of concern in the OU-2 air stream, although the addition of polishing GAC would be required to achieve the required cleanup goal.

<u>Implementability</u>

This technology is compatible with the existing SVE unit and, specifically, could use the existing GAC units for exhaust gas polishing. This is an established, commercially available technology which requires only electrical power for operation. Waste streams would include water condensate, recovered VOCs, and possibly spent GAC media.

This technology will be retained for further consideration.

5.2.9 Flameless Thermal Oxidation

Flameless thermal destruction is a packed bed thermal oxidizer operating at 1600°F to 2000°F. An inert ceramic matrix is used as the packing material to enhance fume mixing and also provide thermal inertia. A DRE of greater than 99 percent with negligible NO_x and CO production is achievable. An enthalpy content of the gas greater than 30 British Thermal Units per standard cubic feet (BTU/scf) will be self-sustaining once operating conditions are met (i.e., no supplemental fuel is required). Prior to operations, the packing material is preheated by a combustion system or electric heaters. The process is currently used for fugitive VOC emission and process offgas abatement. Because the SVE offgas contains chlorinated organics, hydrogen chloride (HCl) will be produced and a caustic scrubber will be necessary to remove and neutralize the HCl prior to discharging the offgas to the atmosphere.

Effectiveness

This technology has a greater than 99 percent removal efficiency for the OU-2 air stream contaminants of concern.

Implementability

Although caustic scrubbing is required, this technology is available and compatible with the existing SVE unit. Additionally, an upstream condenser will be required to remove water from the offgas stream, which will reduce power requirements in the oxidizer as well. Waste streams will include the water condensate and spent caustic from the scrubber.

This technology will be retained for further consideration.

5.2.10 Thermal Oxidation

Thermal oxidation destroys the VOCs by oxidizing the gas stream at temperatures of 1600°F to 2000°F with a residence time of approximately 2 seconds. The oxidation system requires supplemental fuel to increase the gas temperature for treatment. HCl gas is produced, requiring removal and neutralization prior to discharge to the atmosphere.

Effectiveness

This technology has a greater than 99 percent removal efficiency for the OU-2 air stream contaminants of concern.

Implementability

Although caustic scrubbing is required, this technology is available and compatible with the existing SVE unit. Additionally, an upstream condenser will be required to remove water from the offgas stream, which will reduce power requirements in the oxidizer as well. Waste streams will include the water condensate and spent caustic from the scrubber.

This technology will be retained for further consideration.

5.2.11 Catalytic Oxidation

Catalytic oxidation is a process by which VOCs are oxidized in the presence of a catalyst. The offgas is heated to approximately 700°F and passed over a catalyst where it is oxidized to carbon dioxide, water, and HCl. Catalytic oxidation is particularly effective when the treatment stream contains dilute contaminants (i.e., less than 1000 ppm v/v) due to the lower operating temperature (approximately 700°F) required for oxidation (thermal incinerators typically run greater than at 1600°F). High contaminant loading rates may cause heat build-up within the catalyst. However, if the contaminant loading rate is known, the system can be designed to alleviate the heat build-up. The process is continuous and can be implemented either as a once-through process or using recuperative heat exchange to lower operating costs. Conversion efficiencies can range from 90 to greater than 99 percent removal of contaminants depending on residence time and the specific catalyst.

Effectiveness

This technology has the potential to meet the cleanup goal, but is more applicable to dilute contaminant streams (i.e., less than 1,000 ppm v/v).

Implementability

Although this technology requires a fuel source for combustion and a caustic scrubber, it is compatible with the existing SVE unit and commercially available. An upstream condenser will be required to remove entrained water. Waste streams will include the condensate as well as spent caustic from the scrubber.

This technology will be retained for further consideration.

5.2.12 High Energy Corona

A high voltage electric field is established across a packed bed of dielectric pellets to produce a low-temperature (near ambient temperature) plasma that destroys organics (Battelle 1993). Because treatment occurs at low temperatures, high energy corona is not an incineration process, but is instead classified as an advanced oxidation process (AOP), along with UV oxidation and ozonation among others. In pilot tests of the high energy corona system, 99 percent destruction of TCE occurred at a residence time of 1.2 seconds while 99 percent PCE destruction occurred at 3.3 seconds. Further tests with different dielectric pellet materials have demonstrated increased destruction rates. The system may require inlet humidities to be maintained above 15 percent RH to minimize static charge accumulation and sparking. At higher humidities (90 percent RH and above), longer residence times are required to avoid the formation of significant levels (e.g., 5 ppm v/v carbon tetrachloride) of byproducts. Because the SVE offgas contains chlorinated organics, HCl will be produced and a caustic scrubber will be necessary.

Effectiveness

This technology is applicable to the OU-2 air stream contaminants of concern. Although this is an emerging technology, the expected destruction efficiency is greater than 99 percent.

Implementability

This technology has been pilot tested with an SVE unit and is compatible with the existing SVE unit. Although the maximum VOC concentrations for the flow entering the unit are not currently known, test have been successfully completed with inlet concentrations of 2,500 ppm. This technology will require an upstream condenser and a downstream scrubber to remove HCl produced by the high energy corona. Waste streams will include the condensate and the spent caustic.

This technology will be retained for further consideration.

5.3 RETAINED TECHNOLOGIES

Table 5.3-1 presents the list of potentially applicable technologies for treating the OU-2 SVE offgas. Evaluation comments regarding the effectiveness and implementability of the technologies are presented and each technology is characterized as either retained or not retained for further evaluation. The following technologies will be retained for consideration as part of remedial action alternatives:

- GAC
- Membrane Separation
- Ozone-UV-GAC
- Adsorption/Condensation (Purus)
- Condensation/Refrigeration
- Flameless Thermal Oxidation

TABLE 5.3-1
PRELIMINARY TECHNOLOGY SCREENING SVE OFFGAS

	Effectiveness			Implementability				
Technology	**Applicability**	**Removal Efficiency**	**Potential to Meet Cleanup Goal**	**Technology Maturity**	**O&M Requirements**	**Compatibility**	**Adverse Impacts**	**Retain Yes/No**
GAC with off-site regeneration or disposal	Applicable to contaminants of concern. More applicable to low loading rates.	Greater than 99 percent	Yes. May require large quantities of GAC because of high loading rates.	Commercially available	Remove and replace spent GAC. Will require upstream condenser, and subsequent water treatment.	Currently in the SVE treatment train. Impractical because of anticipated high loadings.	Spent GAC Automatic shut-off for VOC concentrations exceeding 10,000 ppmv	Yes
Membrane Separation	Applicable to chlorinated and non-chlorinated volatile organics.	95 percent removal (GAC polishing would improve the removal efficiency)	Yes, with GAC polish	Commercially available	Large power supply for the compressor, vacuum pumps, and refrigeration.	Equipment available. Compatible with the SVE unit.	GAC polishing required; A VOC contaminated aqueous phase and potentially an organic phase.	Yes
Biofiltration	Cannot process contaminants of concern	N/A	No	N/A	N/A	N/A	N/A	No
Chemical Reduction	Cannot be used to process streams with oxygen	N/A	N/A	N/A	N/A	N/A	N/A	No

TABLE 5.3-1
PRELIMINARY TECHNOLOGY SCREENING SVE OFFGAS

	Effectiveness			Implementability				
Technology	**Applicability**	**Removal Efficiency**	**Potential to Meet Cleanup Goal**	**Technology Maturity**	**O&M Requirements**	**Compatibility**	**Adverse Impacts**	**Retain Yes/No**
Photo-Dehalogenation	Dehalogenated contaminants of concern, but VOCs are produced	Unknown	Unknown	Emerging	Requires H_2 gas or natural gas	Equipment not commercially available.	Requires further VOC treatment and scrubbing for HCl. A secondary treatment would be required to treat the dehalogenated VOCs.	No
Ozone-UV-GAC	Applicable to chlorinated and non-chlorinated volatile organics.	Greater than 99 percent removal.	Yes	Commercially available	Power, Acid Scrubbing Water. Will require upstream condenser	Equipment available. Compatible with the SVE unit.	Caustic Scrubbing.	Yes
Adsorption/ Condensation (Purus)	Applicable to contaminants of concern.	Greater than 99 percent removal	Yes	Commercially available	Requires electrical power. Will require an upstream condenser.	Equipment available. Technology compatible with the SVE unit.	A VOC contaminated aqueous phase and potentially an organic liquid phase.	Yes

TABLE 5.3-1
PRELIMINARY TECHNOLOGY SCREENING SVE OFFGAS

Technology	Effectiveness			Implementability				
	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O&M Requirements	Compatibility	Adverse Impacts	Retain Yes/No
Condensation/ Refrigeration	Applicable to contaminants of concern	Greater than 99 percent with GAC polishing.	Yes with GAC polishing	Commercially available	Requires electric power	Equipment commercially available. Compatible with the SVE unit.	GAC polishing required; A VOC contaminated aqueous phase and potentially an organic liquid phase.	Yes
Flameless Thermal Oxidation	Applicable to chlorinated and non-chlorinated VOCs.	Greater than 99 percent Destruction	Yes	Commercially available	Supplemental fuel and/or electrical power. Will require an upstream condenser	Equipment Available. Technology is compatible with the SVE unit as configured.	Caustic Scrubbing Required	Yes
Thermal Oxidation	Applicable to chlorinated and non-chlorinated volatile organics.	Greater than 99 percent Destruction	Yes	Commercially available	Requires a large volume of combustion fuel. Will require an upstream condenser.	Equipment available. Technology is compatible with the SVE unit as configured.	Caustic scrubbing required.	Yes

TABLE 5.3-1

PRELIMINARY TECHNOLOGY SCREENING SVE OFFGAS

	Effectiveness			Implementability				
Technology	**Applicability**	**Removal Efficiency**	**Potential to Meet Cleanup Goal**	**Technology Maturity**	**O&M Requirements**	**Compatibility**	**Adverse Impacts**	**Retain Yes/No**
Catalytic Oxidation	More applicable to streams containing less than 1000 ppmv of organics	Greater than 99 percent Destruction	Yes	Commercially available	Requires a moderate volume of combustion fuel. Will require an upstream condenser.	Equipment Available. Technology is compatible with the SVE unit as configured.	Caustic Scrubbing Required Maximum inlet concentration (with no dilution) of 5,000 ppmv	Yes
High Energy Corona	Applicable to chlorinated and non-chlorinated VOCs.	Greater than 99 percent PCE Destruction	Yes	Emerging (Pilot Tested)	Power required. Will require an upstream condenser.	Full-scale systems have not been constructed or tested. The pilot system was designed and tested with an SVE system.	Caustic Scrubbing required.	Yes

- Thermal Oxidation
- Catalytic Oxidation
- High Energy Corona

6.0 DEVELOPMENT AND EVALUATION OF ALTERNATIVES

This section develops each of the retained technologies into alternatives and describes how each of these technologies would be incorporated with the existing SVE pilot unit. The development of alternatives includes identifying assumptions for design capacity, installation, and operations. These alternatives are then evaluated with respect to effectiveness, implementability and cost, and a comparison of alternatives is performed. Advantages and disadvantages for integration with the SVE unit are also described. The following alternatives are identified for providing offgas treatment for the existing SVE Pilot Unit and the SPSH:

- Existing GAC treatment with offsite regeneration or disposal
- Membrane separation
- Ozone - UV - GAC
- Adsorption/Condensation (Purus)
- Condensation/Refrigeration
- Flameless thermal oxidization
- Thermal oxidation
- Catalytic oxidation
- High energy corona

6.1 SUMMARY OF DESIGN CRITERIA

The design criteria for the SVE and SPSH systems have been discussed in detail in Section 4.0. The design criteria used in developing the offgas treatment alternatives are summarized in Table 4.1-7. The SPSH system requirements that have the most impact on the offgas treatment design criteria are presented below:

		Typical	Maximum Steaming
Total Flow Rate (scfm)		300	500
Air Flow Rate (scfm)		150	50
Water Vapor Flow Rate	(scfm)	150	450
	(gpm)	0.8	2.5
Temperature (°F)		150	212
Pressure (inches Hg vacuum)		15	15
VOC Concentration (ppmv)		6,500	20,000
VOC removal rate (lbs/hr)		20-30	260
Total Water generated (gallons)		45,000	45,000
VOC Removal Efficiency		>95	>99

In addition, the offgas treatment alternatives need to be flexible, reliable, portable, and proven to the scale being considered to meet the needs of the pilot tests. Each of the alternatives needs to incorporate of as much of the existing SVE equipment as possible into the overall treatment system.

6.2 DEVELOPMENT AND SCREENING OF ALTERNATIVES

Each of the retained technologies is developed into an offgas treatment alternative based on the above design criteria and described in the following sections. The alternative descriptions include process flow diagrams (PFDs), waste by-products, identification of new major equipment, modifications to the existing equipment, and utility requirements. Cost estimates are prepared for each alternative. Each of these alternatives is then evaluated with respect to effectiveness, implementability, and cost following the description of the alternative. Table 6.2-1 summarizes key components of the effectiveness and implementability of each alternative. A summary of the overall evaluation is shown on Table 6.2-2.

6.2.1 Existing GAC Alternative with Off-site Regeneration or Disposal

The existing SVE system with GAC offgas treatment is housed in a portable semi-truck trailer that can be moved to various sites to conduct pilot tests of the SVE technology. The system is designed for an extraction capacity of 300 scfm at 10 inches of Hg vacuum. The system process flow is shown in Figure 6.2-1. The extraction system uses two blowers in series to provide vacuum generation capabilities. Two blowers were used for this application to minimize the size of the vacuum system to fit inside the trailer. The existing offgas treatment system includes a knockout drum with a demister pad to remove entrained liquids from the extracted soil gas. During the SPSH pilot test, a condenser would be installed upstream of the knockout drum to remove water vapor or steam from the extracted soil gas stream. The condensed water may require further treatment via air stripping prior to disposal. The exhaust gas from the air stripper would be routed back to the inlet of the existing knockout drum to remove any entrained liquid. The condensate may require storage in additional storage tanks.

The extracted soil gas stream is routed through HEPA filters to remove particulates prior to treatment with GAC. There is a potential that radioactive isotopes attached to particulates may be extracted with the soil gas. If the GAC becomes contaminated with radioactive particles, it would become a mixed waste and limit the disposal or regeneration options.

The two existing GAC units, 1,800 pounds each, are installed between the two extraction blowers. The VOC concentrations in the gas stream after the second GAC unit are expected to be at or near non-detect levels. When organic breakthrough is observed between the two units, the lead unit will be taken off line. The GAC media will be removed and replaced with new media, and the original lead unit put back on line as the second unit with the other

TABLE 6.2-2

ALTERNATIVE EVALUATION FOR SVE OFFGAS

Alternative	Effectiveness	Implementability	Cost
Existing GAC with Off-site Generation or Disposal	Effective in meeting cleanup goal. Greater than 99 percent VOC removal.	GAC is readily available. Addition of a condenser would require minimal modification to the existing system. Generates spent GAC that will require disposal or regeneration.	Capital: $1.2 to $1.5 million O&M: $132,000 to $136,000
Membrane Separation	Effective in meeting cleanup goal. Greater than 99 percent VOC removal.	Commercially available and compatible with existing equipment with major modifications. Generates a concentrated organic liquid that will require further treatment/disposal.	Capital: $650,000 to $985,000 O&M: $110,000 to $130,000
Ozone-UV-GAC	Effective in meeting cleanup goal with recycling of GAC adsorbate. Greater than 99 percent VOC removal by destruction.	Commercially available and compatible with existing equipment with major modifications. Generates spent caustic that will require disposal.	Capital: $680,000 to $1.0 million O&M: $100,000 to $120,000
Adsorption/Condensation (Purus)	Effective in meeting cleanup goal. 99 percent VOC removal.	Commercially available and compatible with existing equipment with moderate modifications. Generates a concentrated organic liquid that will require further treatment/disposal.	Capital: $800,000 to $1.1 million O&M: $125,000 to $140,000
Condensation/ Refrigeration	Effective in meeting cleanup goal. Greater than 99 percent VOC removal.	Commercially available and compatible with existing equipment with major modifications. Generates a concentrated organic liquid that will require further treatment/disposal.	Capital: $580,000 to $915,000 O&M: $110,000 to $125,000

TABLE 6.2-2
(Concluded)

Alternative	Effectiveness	Implementability	Cost
Flameless Thermal Oxidation	Effective in meeting cleanup goal. Greater than 99 percent VOC removal by destruction.	Commercially available and compatible with existing equipment with moderate modifications. Generates spent caustic that will require disposal.	Capital: $1.0 to $1.5 million O&M: $125,000 to $160,000
Thermal Oxidation	Effective in meeting cleanup goal. Greater than 99 percent VOC removal by destruction.	Commercially available and compatible with existing equipment with moderate modifications. Generates spent caustic that will require disposal.	Capital: $240,000 to $870,000 O&M: $80,000 to $105,000
Catalytic Oxidation	Effective in meeting cleanup goal. 99 percent VOC removal by destruction.	Commercially available, compatible with existing equipment with moderate modifications, and proven technology on full scale application. Generates spent caustic that will require disposal.	Capital: $370,000 to $1.0 million O&M: $85,000 to $100,000
High Energy Corona	Effective in meeting cleanup goal. 99 percent VOC removal (destruction) expected.	Commercially available but not proven in full scale application. compatible with existing equipment with moderate modifications. Generates spent caustic that will require disposal.	Capital: $250,000 to $760,000 O&M: $70,000 to $100,000

GAC unit now as the lead unit.

Effectiveness

This alternative would remove greater than 99 percent of the VOCs from the soil gas stream. However, due to the high design concentrations of VOCs entering the GAC units, the GAC media will become saturated rapidly. GAC replacement will be required approximately every 18 hours.

Implementability

The majority of the equipment for this alternative is already at the site. The alternative does require the addition of a condenser and potentially an air stripper and storage tanks to manage the water. System operation requirements are limited to nominal electrical use and virgin or regenerated GAC. By-products include HEPA filters, spent GAC media that may be disposed or regenerated off site, and condensate that may be discharged from the site.

The reliability of the GAC alternative for treating VOCs is high. GAC has been used extensively to treat CCl_4 and other CHCs. The system is easily expanded to accommodate a higher VOC loading by installing more GAC columns, either in series or parallel. Typical costs of an additional GAC vessel is $15,000. The GAC alternative is a fairly simple process with few major unit operations which include condensation, GAC adsorption for VOC removal, and potentially air stripping.

Cost

Capital and O&M cost estimates for the existing GAC alternative are shown in the Appendix on Tables A-1 and A-2. Capital costs range from approximately $1.2 to $1.5 million depending upon the disposition of the by-products. O&M costs range from approximately $132,000 to $136,000.

6.2.2 Membrane Separation Alternative Using GAC Polishing

The membrane separation system consists of a compressor, refrigeration unit, and membrane module as shown in Figure 6.2-2. Upstream of the system, a condenser and knockout drum would remove the bulk of the moisture from the extracted gas stream. The condensate may require treatment via an air stripper and storage. The exhaust gas from the air stripper would re-enter the soil gas stream prior to the inlet of the knockout drum. The membrane separation system first uses a compressor to increase the soil gas stream pressure to 150 psig and a refrigerant cooled heat exchanger to cool the soil gas stream to 35°F. Condensate is removed and pumped to a storage tank. The soil gas stream then enters the membrane module, where it is separated into a VOC rich stream and a VOC depleted stream. The VOC rich stream is returned to the inlet of the compressor for reprocessing, and the VOC depleted stream is passed to the existing GAC units for polishing prior to discharge to the atmosphere.

Modifications to the existing SVE unit include installation of a condenser upstream of the knockout drum, potential addition of an air stripper system to treat the condensate, and addition of the associated pumps and storage tanks. The membrane separation unit would be a separate skid-mounted unit that would require piping modifications for installation upstream of the existing GAC units.

<u>Effectiveness</u>

This alternative would remove greater than 99 percent of the chlorinated hydrocarbons. The membrane separation process operated as described above requires GAC as a polishing step to remove CCl_4. This alternative with GAC polishing can meet the cleanup goal.

Implementability

The equipment for this alternative is commercially available, and can be incorporated with the existing SVE equipment. This would require major modifications to the piping and existing system to install the membrane system between the knockout drum and GAC vessels. This alternative has no limit on the VOC inlet concentration or water content of the soil gas stream. The power requirement for this alternative is approximately 83 kW at 300 scfm, and 167 kW at 600 scfm. By-products of this alternative would include the HEPA filters, potentially spent GAC, condensate which may require treatment prior to disposal, and a concentrated organic liquid that would require off site treatment and disposal.

Cost

Capital and O&M cost estimates for the membrane separation alternative are shown in the Appendix on Tables A-3 and A-4. The cost of the membrane separation unit is $200,000. Capital costs with supporting equipment required for this treatment alternative range from approximately $650,000 to $985,000 with O&M costs ranging from approximately $110,000 to $130,000.

6.2.3 Ozone-UV-GAC Alternative

The ozone-UV-GAC system consists of three separate skid-mounted units that include a gas phase photolytic reaction chamber, a mist air dispersion reactor and two existing GAC units as shown in Figure 6.2-3. A heat exchanger (cooler) would reduce the temperature of the soil gas stream. The extracted soil gas would enter the gas phase photolytic reactor chamber where the organics are oxidized by UV light in the presence of activated oxygen (ozone and hydrogen peroxide). The soil gas stream is further oxidized and scrubbed in the mist air dispersion reactor and then transported to the existing GAC units. An activated oxygen generation system is required to support oxidation and the GAC regeneration step. The remaining VOCs and ozone in the soil gas stream are adsorbed on the GAC. Once the GAC is loaded and breakthrough is expected, the units are regenerated with ozone. Oxidation of chlorinated VOCs will generate HCl in the exhaust gas that requires scrubbing. A caustic scrubbing system is included with the aqua reactor to provide offgas treatment for acid gas removal. Chlorine would normally be expected to ultimately reduce GAC adsorption capacity, but at the loading rate anticipated it is not expected to degrade the GAC to a level that requires it to be replaced during the life of the pilot study.

A new fan, in addition to the existing blowers, will provide a minimal pressure drop across the ozone-UV-GAC unit. The ozone-UV-GAC alternative will incorporate the SVE equipment into the overall system. By-products from the system include the HEPA filters. The soil gas stream purged from the GAC vessels will be returned to the beginning of the treatment unit. The only additional waste product is the spent caustic scrubbing solution that may require treatment prior to disposal.

<u>Effectiveness</u>

This alternative destroys greater than 95 percent of CCl_4, PCE, and TCE on the first pass. This alternative meets the requirements for the cleanup goal.

<u>Implementability</u>

The equipment for this alternative is commercially available and can be incorporated into the existing SVE system with major modifications. This system has no limitations on VOC inlet concentration. This alternative requires an upstream heat exchanger (cooler), approximately 14 kW of electrical power, caustic, water and replacement ultraviolet lamps. By-products that will be generated include spent caustic, UV lamps, HEPA filters, and eventually exhausted carbon.

This is a relatively new technology with a single vendor. There are 3 systems currently operating which treat CHCs, but CCl_4 is not the primary contaminant at these sites.

Therefore, the probability of reliable performance is estimated to be low to moderate. Expandability of the system is achievable by installing another activated oxygen generator. This alternative employs numerous unit operations including the photolytic oxidation, scrubbing, activated oxygen generation, and adsorption.

Cost

Capital and O&M cost estimates for the ozone-UV-GAC alternative are shown in the Appendix on Tables A-5 and A-6.

The cost of the ozone-UV-GAC unit is $285,000. With the supporting equipment required for this treatment alternative, the capital cost is approximately $680,000 to $1.0 million. Operating and maintenance costs per quarter are approximately $100,000 to $120,000.

6.2.4 Adsorption/Condensation Alternative Using Purus Technology

Under this alternative, the extracted soil gas stream will first pass through a condenser and the existing knockout drum to remove significant quantities of water from the gas stream. The condensate may require treatment via an air stripper to remove entrained VOCs before storage or disposal. The gas stream from the condenser will pass through HEPA filters to remove particulates. The condenser will cool the gas stream to approximately 50°F. The maximum inlet temperature for the Purus module is 120°F. The Purus system would be installed after the lead blower as shown in Figure 6.2-4. A series of adsorption beds would remove the VOCs from the extracted soil gas. As one set of beds is treating, the other set is being regenerated. The regeneration process uses internal heating coils in the adsorption beds to evaluate the temperature of the adsorbent. A vacuum pump also lowers the operation pressure to help volatize the VOCs. The VOCs from the regeneration cycle are condensed in a two-stage condenser system operation. A mechanical refrigeration system provides coolant for the condensing step. Nitrogen gas is also used to purge the adsorption bed of VOCs prior to cycling back for treatment. The concentrated organic liquid is transferred to an on-site storage tank for eventual disposal. The pressure drop across the Purus module is 16 to 20 inches of water column.

Modifications to the existing SVE unit include installation of a new condenser before the existing knockout drum, potential addition of an air stripper system to treat the condensate, and addition of the skid-mounted Purus module. By-products include HEPA filters, condensate and the concentrated organic liquid. The concentrated organic liquid would require offsite treatment and disposal.

Effectiveness

This alternative would remove 95 to 99 percent of the CCl_4, and 99 percent of the PCE and TCE, the major contaminants in the gas stream. It removes both chlorinated and non-chlorinated compounds, and thus can meet the cleanup goal.

Implementability

The Purus technology in this alternative is technologically mature and commercially available. This alternative can be merged with the existing equipment with moderate modifications. High VOC inlet concentrations can be accepted but the loading on the resins and desorption rate would be affected. A soil gas stream with 100 percent relative humidity can be accepted by this alternative. This alternative requires approximately 20 to 30 kW of electrical power and compressed nitrogen gas. By-products include the condensate and the concentrated organic liquid that would require off site treatment and disposal.

While this is a relatively new technology with a single vendor, there are about ten full scale units treating CHCs. Therefore, the probability of reliable performance is estimated to be moderate. The adsorbent beds are modular units, allowing easy additions to increase the removal capacity. This alternative involves numerous unit operations including condensation, air stripping, adsorption and refrigeration.

Cost

Capital and O&M cost estimates for the adsorption/condensation alternative are shown in the Appendix on Tables A-7 and A-8.

The cost of the Purus module is $300,000. With the supporting equipment required for this treatment alternative, the capital cost is approximately $800,000 to $1.1 million. Operating and maintenance costs per quarter are approximately $125,000 to $140,000.

6.2.5 Condensation/Refrigeration Alternative Using GAC Polishing

The condensation/refrigeration system is shown in Figure 6.2-5. The extracted soil gas stream will pass through a condenser to remove significant quantities of water from the gas stream. The condensate will be collected and may require treatment via air stripping to remove VOCs before storage or disposal. The soil gas stream exiting the condenser at 40°F will pass through HEPA filters to remove particulates. The condensing system will be installed after the lead blower, and the existing GAC units (or new regenerable type, high efficiency GAC units) and second blower could be used in their existing configurations. The condensers would be skid mounted and installed adjacent to the trailer. A mechanical refrigeration system would provide cooling media to lower the soil gas stream temperature and promote further condensing of VOCs. Because the operating temperature of -30°F is well below the freezing point of water, dual heat exchanger units would be installed in parallel. The system will be automatically switched over to the second heat exchanger while the original system thaws. The concentrated organic liquid would require offsite treatment and disposal. The condensing system with the existing GAC units will provide a VOC removal efficiency of greater than 99 percent.

Modifications to the existing SVE unit would include installation of a condenser upstream of the knockout drum, potential addition of an air stripper system to treat the condensate, and addition of a skid-mounted refrigeration system with a recovery tank upstream of the existing

GAC units. This alternative would generate potentially spent GAC and a concentrated organic liquid that would require further treatment and disposal. Other by-products requiring disposal include the condensate and HEPA filters.

Effectiveness

This alternative would remove greater 99 percent of CCl_4, PCE, and TCE, in addition to non-chlorinated and other chlorinated compounds in the soil gas stream. The GAC is required for polishing to adsorb primarily CCl_4, which is difficult to condense. This alternative can meet the cleanup goal.

Implementability

The equipment for this alternative is commercially available and is typical of the processes used in the chemical manufacturing industry. Therefore, this type of process would be moderate in reliability. This alternative would require major modifications to incorporate the existing equipment. This alternative has no restrictions on the VOC inlet concentration or water content of the soil gas stream. The power requirements are approximately 44 kW. This process involves numerous unit operations including condensation, refrigeration, air stripping, and adsorption. Multiple units could be added to expand the capability of this system. By-products include a condensate, HEPA filters, potentially spent carbon, and the concentrated organic liquid that requires offsite treatment and disposal.

Cost

Capital and O&M cost estimates for the condensation/refrigeration alternative are shown in the Appendix on Tables A-9 and A-10.

The cost of the condensation/refrigeration equipment is $176,000. With the supporting equipment required for this treatment alternative, the capital cost is approximately $580,000 *to $915,000. Operating and maintenance costs per quarter are approximately $110,000 to $125,000.*

6.2.6 Flameless Thermal Oxidation Alternative

The flameless thermal oxidizer would replace the existing GAC unit as shown in Figure 6.2-6. The soil gas stream would pass through a condenser to remove most of the water. The condensate will be removed and may require treatment by an air stripping system prior to storage and disposal. The soil gas stream would pass through HEPA filters to the flameless thermal oxidizer system. The oxidizer is a carbon steel shell with refractory lining and contains a packed bed matrix that supports the oxidation process. The oxidizer operates at approximately 1800°F. The integral electric preheater is used to heat the oxidizers' ceramic bed on system startup and provide supplemental energy as needed to maintain the matrix at the operating temperature. The VOCs are oxidized to CO_2, H_2O, and HCl. The exhaust gas from the oxidizer goes through a quench unit *for cooling. The exhaust gas is routed to a* scrubber where the HCl would be neutralized by caustic scrubbing. The scrubber system would include a caustic supply tank, fresh water supply tank, scrubber with recirculation pump, and a spent caustic solution storage tank. No treatment of the spent scrubber solution is assumed at the pilot test site. The scrubber system could be installed on the oxidizer skid or on a separate skid. The scrubber system, caustic storage and mixing systems are assumed to be inside a secondary containment area or designed with double walled system and leak detection.

The existing lead blower in the SVE pilot unit should generate enough pressure without limiting the vacuum generation capability. The existing configuration of the two blowers operating in series will have to be modified as the thermal oxidizer and scrubber system are typically not designed for the vacuum pressures the SVE system can generate. There is also the potential that the existing blower may also need to be replaced with one blower. The flameless thermal oxidizer would be an external skid mounted unit. The organic treatment will be operated above atmospheric pressure. This system can be designed, installed, and operated to provide the necessary treatment without having all the treatment system designed for vacuum operation.

Modifications to the existing SVE unit would include installation of a condenser upstream of the existing knockout drum, potential addition of an air stripper system, and the installation of the skid-mounted flameless thermal oxidizer system with potentially a caustic scrubber unit.

The only by-products from this alternative would be the condensate, potentially a spent caustic solution, and HEPA filters.

Effectiveness

This alternative would remove greater than 99 percent of the CCl_4, PCE and TCE in addition to nonchlorinated and other chlorinated compounds in the gas stream, and would meet the cleanup goal.

Implementability

The flameless thermal oxidation system is commercially available and has been used at sites for treatment of non-chlorinated and chlorinated compounds. This oxidation system can be incorporated into the existing equipment with moderate modifications. The oxidizer system requires approximately 45 to 76 kW power. This alternative has no limitations on inlet VOC concentrations.

The capacity or size of the flameless thermal oxidizer system could be expanded in the design phase by including a larger blower, larger burner, and additional valving which may add some to the capital costs. This alternative includes several unit operations including condensation, air stripping, flameless thermal oxidization, and acid gas scrubbing. The by-products from this alternative, condensate and spent caustic, may require treatment prior to disposal.

Cost

Capital and O&M cost estimates for the Flameless Thermal Oxidation Alternative are shown in the Appendix on Tables A-11 and A-12. The cost of the flameless thermal oxidizer equipment is $380,000. Total capital costs with the supporting equipment required for this treatment alternative are approximately $1.0 to $1.5 million. Operating and maintenance costs per quarter are approximately $125,000 to $160,000.

6.2.7 Thermal Oxidation Alternative

The thermal oxidation unit would be a skid-mounted unit, nominally 6 feet wide by 12 feet long, replacing the existing GAC units as shown in Figure 6.2-7. The extracted soil gas stream would pass through a condenser operating at 40°F to remove the majority of the water. The condensate would be removed and may require treatment via an air stripper prior to storage and disposal. The soil gas stream would go through HEPA filters for particulate removal. After exiting the filters, the soil gas stream would enter the thermal oxidizer. A porous ceramic burner mixes the soil gas and air stream and fuel before combustion in the thermal oxidizer. The oxidizer operating temperature ranges from 1600°F to 1800°F. The exhaust gas from the oxidizer contains HCl and may require further treatment before discharge to the atmosphere. The exhaust gas would undergo scrubbing with a caustic solution in the acid gas scrubber to remove greater than 99 percent of the acid. The scrubber system would include a caustic supply tank, fresh water supply tank, scrubber with recirculation pump, and a spent caustic solution storage tank. No treatment of the spent caustic solution is assumed at the pilot test site. The scrubber system, caustic storage, and mixing systems are assumed to be designed with double walls and leak detection.

The existing lead blower in the SVE pilot unit should generate enough pressure generation capacity without limiting the vacuum generation capability. The existing configuration of the two blowers operating in series will have to be modified as the oxidizer and scrubber system are typically not designed for the vacuum pressures the SVE system can generate. There is fuel for maintaining the oxidizer temperature. The pressure drop across the catalytic oxidizer system is 8 inches of water column. The inlet concentration to the oxidizer has a limit of 5,000 ppm VOC and can operate at 100 percent relative humidity in the gas stream. For higher inlet concentrations, dilution air is required to reduce the concentrations. At high relative humidities, additional fuel is required.

The technology has been used at more than a dozen sites at full scale operation to treat CHCs. Therefore, its reliability would be moderate to high. Enlargement of the system in the design phase is preferable to modifying an existing system. This advance design will allow for partitioning of the catalyst site, to scale up if necessary. This alternative includes several unit operations including condensation, air stripping, catalytic oxidization, and acid gas scrubbing.

Cost

Capital and O&M cost estimates for the catalytic oxidation alternative are shown in the Appendix on Tables A-15 and A-16. The cost of the catalytic unit is $92,725. Total capital costs with the supporting equipment required for this treatment alternative are approximately $370,000 to $1.0 million. Operating and maintenance costs per quarter are approximately $85,000 to $100,000.

6.2.9 High Energy Corona Alternative

The high energy corona system would replace the existing GAC unit as shown on Figure 6.2-8. The extracted soil gas stream would pass through a condenser to remove most of the water. The condensate may require treatment via an air stripper to remove dissolved VOCs prior to storage and disposal. The soil gas stream from the condenser will pass through HEPA filters to remove particulates. The soil gas stream then passes through the high energy corona reactors where the high voltage current ionizes the air forming a low temperature plasma. The plasma is expected to destroy a wide variety of organic compounds in air. As also the potential that the existing blowers may also need to be replaced with one blower. The organic treatment will be operated above atmospheric pressure. This system can be designed, installed, and operated to provide the necessary treatment without having all the treatment system designed for vacuum operation. A propane storage tank would be used to provide fuel for startup and supplemental fuel for operation.

Modifications to the existing SVE unit include installation of a condenser upstream of the existing knockout drum, potential addition of an air stripper system, installation of the skid-mounted thermal oxidizer system with potentially a caustic scrubber unit.

By-products from this alternative would be HEPA filters and potentially a spent caustic solution that may require further treatment prior to disposal. The exhaust gas from this alternative contains less than 5 ppm NO_x.

Effectiveness

This alternative would remove greater than 99 percent of the CCl_4, PCE and TCE in addition to nonchlorinated and other chlorinated compounds in the gas stream and would meet the cleanup goal.

Implementability

The thermal oxidation system is commercially available and has been proven to be effective at removing CCl_4. The existing equipment can be incorporated into this alternative with moderate modifications. This oxidizer system requires approximately 4 kW of electric power and propane as the fuel source. This alternative has a 5,000 to 6,000 ppm maximum VOC concentration limit on the inlet to the oxidizer. The pressure drop across the thermal oxidizer is 5 inches of water column. The oxidizer system operates more effectively with air streams at less than 80 percent relative humidity. More water vapor content increases the fuel and air consumption.

The thermal oxidation technology is commercially available. The capacity or size of the thermal system could be expanded in the design phase by including a larger blower, larger burner, and increased valving which may add some to the capital costs. This alternative includes several unit operations including condensing, air stripping, thermal oxidization, and acid gas scrubbing.

Cost

Capital and cost estimates for the thermal oxidation alternative are shown in the Appendix on Tables A-13 and A-14. The cost of the thermal oxidizer equipment is $50,000. Total capital costs with the supporting equipment required for this treatment alternative are approximately $240,000 to $870,000. Operating and maintenance costs per quarter are approximately $80,000 to $105,000.

6.2.8 Catalytic Oxidation Alternative

The catalytic oxidation system would be similar to the thermal oxidation as shown in Figure 6.2-7. The extracted soil gas stream would pass through a condenser to remove the majority of the water. The condensate may require treatment via air stripping prior to storage and disposal. The soil gas stream then goes through the HEPA filters and on to the catalytic oxidizer. The catalytic oxidizer operates at an inlet temperature of 650°F and an exhaust temperature of 850-950°F. The soil gas stream passes through the catalyst where an exothermic reaction converts the VOCs to CO_2, water, and HCl.

The exhaust gas from the oxidizer may require further treatment to neutralize HCl. The scrubber system would include a caustic supply tank, fresh water supply tank, scrubber with recirculation pump, and a spent caustic solution storage tank. No treatment of the spent caustic solution is assumed at the pilot test site. The scrubber system and caustic storage tanks are assumed to be inside a secondary containment area or designed with double walls and leak detection.

The existing lead blower in the SVE pilot unit should generate enough pressure capacity without limiting the vacuum generation capability. The existing configuration of the two blowers operating in series will have to be modified as the oxidizer and scrubber system are typically not designed for the vacuum pressures the SVE system can generate. There is also the potential that the existing blowers may also need to be replaced with one blower. The organic treatment will be operated above atmospheric pressure. This system can be designed, installed, and operated to provide the necessary treatment without having all the treatment system designed for vacuum operation. A propane storage tank would be used to provide fuel for startup and supplemental fuel for operation.

Modifications to the existing SVE unit include installation of a condenser upstream of the existing knockout drum, potential addition of an air stripper system, and installation of the skid-mounted catalytic oxidizer system with the caustic scrubber unit.

This alternative would generate a spent caustic solution that may require further treatment prior to disposal. The exhaust gas would contain approximately 40 ppm of NO_x at 3 percent oxygen.

<u>Effectiveness</u>

This alternative would remove greater than 99 percent of the CCl_4, PCE, and TCE in addition to nonchlorinated and other chlorinated compounds in the air stream and would meet the cleanup goals.

<u>Implementability</u>

The catalytic oxidation system is commercially available and has been proven on a full scale operation to be effective at removing CCl_4, PCE, and TCE. The existing equipment could be modified and incorporated into the overall treatment system with moderate modifications. The oxidizer system requires only 8 kW of electrical power, but would require supplemental fuel for maintaining the oxidizer temperature. The pressure drop across the catalytic oxidizer system is 8 inches of water column. The inlet concentration to the oxidizer has a limit of 5,000 ppm VOC and can operate at 100 percent relative humidity in the gas stream. For higher inlet concentrations, dilution air is required to reduce the concentrations. At high relative humidities, additional fuel is required.

The technology has been used at more than a dozen sites at full scale operation to treat CHCs. Therefore, *its reliability would be moderate to high. Enlargement* of the system in the design phase is preferable to modifying an existing system. This advance design will allow for partitioning of the catalyst site, to scale up if necessary. This alternative includes several unit operations including condensation, air stripping, catalytic oxidization, and acid gas scrubbing.

Cost

Capital and O&M cost estimates for the catalytic oxidation alternative are shown in the Appendix on Tables A-15 and A-16. The cost of the catalytic unit is $92,725. Total capital costs with the supporting equipment required for this treatment alternative are approximately $370,000 to $1.0 million. Operating and maintenance costs per quarter are approximately $85,000 to $100,000.

6.2.9 High Energy Corona Alternative

The high energy corona system would replace the existing GAC unit as shown on Figure 6.2-8. The extracted soil gas stream would pass through a condenser to remove most of the water. The condensate may require treatment via an air stripper to remove dissolved VOCs prior to storage and disposal. The soil gas stream from the condenser will pass through HEPA filters to remove particulates. The soil gas stream then passes through the high energy corona reactors where the high voltage current ionizes the air forming a low temperature plasma. The plasma is expected to destroy a wide variety of organic compounds in air. As the destruction of VOCs in the SVE offgas produces HCl, a caustic scrubber may be used to neutralize the HCl in the exhaust gas stream.

Modifications to the system include addition of the condenser upstream of the existing knockout drum, potential addition of an air stripper system, installation of the skid-mounted high energy corona system and potentially the scrubber system (including a caustic supply tank, fresh water supply tank, scrubber with recirculation pump, and a spent caustic solution storage tank).

This alternative generates a spent caustic waste which may require treatment prior to disposal. The concentration of NO_x from the offgas is approximately 1 ppm.

Effectiveness

This alternative would remove 99 percent of the CCl_4, PCE and TCE in addition to nonchlorinated and other chlorinated compounds on the gas stream and be able to meet the cleanup goal.

Implementability

The high energy corona system is commercially available, but has not been proven to be effective at removing CCl_4, PCE and TCE on a full scale. The existing equipment can be incorporated into this alternative with moderate modification. The oxidizer system requires approximately 15 kW power. This technology has been tested on air streams with VOC concentrations of up to 2,500 ppm and 100 percent relative humidity.

Since this is a new technology, with no full scale applications and only one field pilot test, the probability of reliable performance is estimated to be low. The high energy corona reactors are modular, and can be easily expanded for minimal cost. This alternative involves only a few unit operations including condensation, air stripping, high energy corona reaction, and acid gas scrubbing.

<u>Cost</u>

Capital and O&M cost estimates for the HEC are shown in the Appendix on Tables A-17 and A-18. The cost of the plasma oxidization equipment is $43,000. Total capital costs with supporting equipment required for this treatment alternative are approximately $250,000 to $760,000. Operating and maintenance costs per quarter are approximately $70,000 to $100,000.

6.3 COMPARISON OF ALTERNATIVES

The alternatives described and evaluated in Section 6.2 are further evaluated by comparison to each other. Tables 6.2-1 and 6.2-2 present how each alternative meets key requirements such as implementability, reliability, commercial availability, and expendability and summarizes the effectiveness, implementability, and cost of each alternative.

All of the alternatives are capable of achieving the VOC removal efficiency of 95 percent or greater. Ozone-UV-GAC has achieved greater than 95 percent in the past for similar VOCs.

The adsorption/condensation, catalytic oxidation, and high energy corona alternatives each have been reported to achieve 99 percent removal of VOCs. Condensation/refrigeration, flameless thermal, and thermal oxidation alternatives have been reported to achieve greater than 99 percent removal of VOCs.

The thermal, catalytic and high energy corona oxidation alternatives have limits on the VOC concentration in the inlet gas stream. The thermal and catalytic alternatives have limits to protect the equipment and prevent the possibility of explosion. The high energy corona has been tested with inlet gas concentrations as high as 2,500 ppmv VOCs.

All of the alternatives will require a condensing step to remove the excess water from the soil gas stream. Most of the alternatives could operate at 100 percent relative humidity (RH) inlet conditions but would operate more effectively at less than 100 percent RH.

Only the oxidation alternatives (thermal, catalytic, flameless thermal, and high energy corona) will generate products of combustion. These products will include HCl and NO_x. Ozone-UV-GAC will generate HCl. NO_x is regulated for this site. All of the alternatives generate small quantities that are within the regulatory limits. HCl is a hazardous air pollutant but is not regulated at this time. For this evaluation, a caustic scrubbing system capable of approximately 99 percent removal has been included as a reasonable control alternative in each of these alternatives. The scrubbing process will generate a spent caustic waste that may require treatment before disposal.

While all of the alternatives are commercially available, three of the technologies (adsorption/condensation, ozone-UV-GAC, and high energy corona) are considered proprietary and available from one source.

Based on the information gathered for this evaluation, none of the alternatives has been used for treatment of CCl_4 as the primary contaminant. All of the alternatives have been used for other chlorinated organics and/or non-chlorinated organics. The adsorption/condensation (Purus) alternative has been demonstrated at more than 10 sites. Most of the other alternatives have been demonstrated at less than 10 sites. The high energy corona has not yet been demonstrated on a full scale application. Some of the alternatives use conventional processes such as condensation, refrigeration, and adsorption that have been used in the chemical industry for years. The oxidation alternatives, particularly thermal, use a process that has been used in the chemical and refining industries for years. The alternatives that use conventional or proven processes will tend to be more reliable than emerging processes.

The simplest alternative with the least number of unit operations is the GAC alternative. The oxidation alternatives would be relatively simple if treatment of the condensate and scrubbing of the exhaust gas to neutralize acids was not required. The VOC recovery type alternatives (adsorption/condensation, condensation/refrigeration, membrane separation) involve more process operations but the processes are conventional. The condensation/refrigeration and membrane separation alternatives could encounter operating problems with icing and thermal cycling.

Several of the alternatives are more flexible and can be expanded more easily even after the system has been built. The GAC, adsorption/condensation, and high energy corona are modular and can be expanded by adding more units. The capacity or size of the thermal, catalytic, and flameless thermal oxidation alternatives would be more easily and cost effectively expanded in the detailed design phase.

The GAC alternative would produce the largest amount of by-product, the spent GAC, that would require offsite treatment and disposal. The VOC recovery type alternatives (adsorption/condensation, condensation/refrigeration, membrane separation) would also generate a significant quantity of concentrated organics that would require treatment and disposal, probably incineration. Therefore, the GAC adsorption/condensation, condensation/refrigeration and membrane separation alternatives will not be retained for further consideration as the off gas treatment alternative.

The ozone-UV-GAC, thermal, catalytic, flameless thermal, and high energy corona are all destruction alternatives. These alternatives would only generate a potentially nonhazardous spent scrubber solution.

As a result of the above comparison the destruction alternatives would appear to be more compatible, reliable, and effective at removing the VOCs. A disadvantage to these systems is the limited flexibility in operation after the system is installed which could limit the operating condition of the SPSH pilot test.

The high energy corona alternative is not retained because the technology is still in the development stage.

The ozone-UV-GAC alternative is not retained because of minimal demonstration of the technology on chlorinated organics (CCl_4 in particular), thereby causing concern over its long-term operational reliability.

Of the conventional oxidation alternatives, the flameless thermal oxidation is the most expensive and the least demonstrated or proven technology. Therefore, the flameless thermal alternative will not be retained.

The thermal and catalytic oxidation alternatives are relatively close in cost. Thermal oxidation, which is similar to flaring performed at chemical plants and refineries, would be a very simple cost effective and reliable method of offgas treatment. However, effectiveness and reliability would depend on the removal efficiency required for this type of unit. Therefore, the catalytic oxidation alternative appears to be the remaining alternative.

6.4 SUMMARY AND RECOMMENDATIONS

As a result of the alternative screening and evaluation process, the thermal and catalytic oxidation alternatives would be recommended as the offgas treatment alternatives.

The thermal oxidation employs a simple, proven process widely used in the chemical and refinery industries. Should this technology be imposed with more stringent removal requirements which may not be attainable during the pilot test, this alternative should not be implemented.

The catalytic oxidation would in that case be the recommended alternative. This technology has been used at numerous sites for destruction of chlorinated organics but at few where CCl_4 has been the primary contaminant. There is potential with this technology for fouling of the catalyst thus requiring downtime and change out of the catalyst. There are limits on the VOC inlet concentrations. Higher concentrations than the typical used in the design basis would require a larger unit to allow for a greater volume of dilution air thus increasing the size of the cadets system. The advantages to this system are the destruction of VOCs and generation of few by-products that could potentially be non-hazardous.

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APPENDIX
COST ESTIMATES FOR OFFGAS TREATMENT ALTERNATIVES

COST ASSUMPTIONS

The cost tables developed for each of the offgas treatment alternatives in this Appendix are order of magnitude estimates. The range of accuracy for these estimates is typically assumed to be +50 percent/-30 percent. The following summarizes the assumptions that were required in order to develop the cost tables for each of the offgas treatment alternatives:

Capital Cost Assumptions:

- The existing GAC alternative capital cost estimate incorporates the cost for replacement carbon. The frequency of GAC replacement is assumed to be every 18 hours based on 15 percent loading and inlet VOC concentration of approximately 6500 ppmv. The cost for GAC replacement includes delivery of virgin carbon and regeneration of the spent carbon.

- A condenser is required to remove water vapor from the SVE gas stream in order to maintain the efficiency of the HEPA filters and to meet requirements of the offgas treatment technologies.

- The condensate stream with entrained VOCs may need to be treated. Two capital and O&M cost tables were developed for each alternative: one with and one without water treatment. For the estimates with water treatment, an air stripper system is included to remove VOCs from the condensate stream, and the treated water will be stored in five 10,000 gallon, double walled tanks. Two 10,000 gallon, double walled tanks from the existing SVE treatment system will be used to temporarily hold the condensate prior to treatment.

- An acid gas scrubber is incorporated in the offgas treatment system to remove HCl from the gas stream for those alternatives using oxidation/destruction technologies. The scrubber system would include double walled tanks for the caustic and the spent caustic and a single walled tank for water storage.

- Propane is assumed to be the fuel supplement for the thermal and catalytic oxidizer alternatives.

- A 10,000 gallon, double walled tank is also required for condensed organic liquid storage for the adsorption/condensation and condensation/refrigeration alternatives that recover VOCs in liquid form.

Operations and Maintenance Cost Assumptions:

- The system will be operated 7 days per week, 24 hours per day for 90 days for Pilot Test Site No. 2.

- It is assumed that two operators are required on site during the entire test period. They will each devote two hours per day to the offgas treatment alternative. A supervisor and a site safety officer will each devote four hours per week to the offgas treatment alternative. Other health and safety costs are due to miscellaneous PPE.

- Electric utility costs are $0.08/kWh.

- Raw materials include propane and caustic. The thermal oxidation alternative was assumed to require twice as much propane as the catalytic oxidizer.

Other Assumptions:

- Permanent electrical power is assumed to be available. Therefore, no costs for operations and maintenance of diesel generators are included.

- Process water is available.

TABLE A-1

CAPITAL/O&M COST ESTIMATE
GAC ALTERNATIVE

DIRECT COSTS					
	Major Purchased Equipment (MPE)		Quantity	Unit Cost	Total Cost
(1)	Replacement GAC (1800 lbs)		120	$4,230	$507,600
(2)	Condensate Pump		1	$1,000	$1,000
(3)	High Volume Condenser		1	$16,000	$16,000
		SUBTOTAL MPE			$524,600
(4)	Miscellaneous Equipment	5% SUBTOTAL MPE			$26,230
	TOTAL MPE				$550,830
(5)	Installation of MPE	5% MPE			$27,542
(6)	Instrumentation and Controls	5% MPE			$27,542
(7)	Piping	8% MPE			$44,066
(8)	Electrical	10% MPE			$55,083
(9)	Site Preparation	5% MPE			$27,542
(10)	Utilities	5% MPE			$27,542
(11)	Buildings and Services	5% MPE			$27,542
		TOTAL DIRECT COSTS (DC)			$787,687
INDIRECT COSTS					
(12)	Engineering, Supervision	5% DC			$39,384
(13)	Construction Expenses	5% DC			$39,384
(14)	Contractor's Overhead and Profit	10% DC			$78,769
		TOTAL INDIRECT COSTS (IC)			$157,537
(15)	Contingency	30% (DC + IC)			$283,567
		TOTAL CAPITAL COSTS			$1,228,792

TABLE A-1
CAPITAL/O&M COST ESTIMATE
GAC ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O&M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$55,083
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (14 kW x $.08/kW-hr x 2,160 hrs)	$2,420
6	Raw Materials	$14,000
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$12,288
9	SUBTOTAL (excluding contractor's fee)	$119,211
10	Contractor's Fee 15% of Labor & maintenance	$13,050
	TOTAL O & M	$132,261

TABLE A-2

CAPITAL/O&M COST ESTIMATE
GAC ALTERNATIVE WITH WATER TREATMENT

DIRECT COSTS					
	Major Purchased Equipment (MPE)		Quantity	Unit Cost	Total Cost
(1)	Replacement GAC (1800 lbs)		120	$4,230	$507,600
(2)	High Volume Condenser		1	$16,000	$16,000
(3)	Condensate pumps		3	$1,000	$3,000
(4)	Air Stripper		1	$10,000	$10,000
(5)	Condensate Storage Tanks		5	$20,000	$100,000
		SUBTOTAL MPE			$636,600
(6)	Miscellaneous Equipment	5% SUBTOTAL MPE			$31,830
	TOTAL MPE				$668,430
(7)	Installation of MPE	5% MPE			$33,422
(8)	Instrumentation and Controls	5% MPE			$33,422
(9)	Piping	8% MPE			$53,474
(10)	Electrical	10% MPE			$66,843
(11)	Site Preparation	5% MPE			$33,422
(12)	Utilities	5% MPE			$33,422
(13)	Buildings and Services	5% MPE			$33,422
		TOTAL DIRECT COSTS (DC)			$955,855
INDIRECT COSTS					
(14)	Engineering, Supervision	5% DC			$47,793
(15)	Construction Expenses	5% DC			$47,793
(16)	Contractor's Overhead and Profit	10% DC			$95,585
		TOTAL INDIRECT COSTS (IC)			$191,171
(17)	Contingency	30% (DC + IC)			$344,108
		TOTAL CAPITAL COSTS			$1,491,134

TABLE A-2
CAPITAL/O&M COST ESTIMATE
GAC ALTERNATIVE WITH WATER TREATMENT
(Concluded)

Item No.	Description	Quarterly O&M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$66,843
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (20.5 kW x $.08/kW-hr x 2160 hr)	$3,550
6	Raw Materials	$0
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$14,911
9	SUBTOTAL (excluding contractor's fee)	$120,724
10	Contractor's Fee 15% of Labor & maintenance	$14,814
	TOTAL O & M	$135,539

TABLE A-3

CAPITAL/O&M COST ESTIMATE
MEMBRANE SEPARATION ALTERNATIVE

DIRECT COSTS

	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Membrane Separation Equipment	1	$200,000	$200,000
	Compressor	1	INCL	
	Vacuum Pump	1	INCL	
	Condenser	1	INCL	
	Membrane Modules	1	INCL	
(2)	Condensate Pump	1	$1,000	$1,000
(3)	10,000 gal VOC Recovery Tank	1	$20,000	$20,000
		SUBTOTAL MPE		$221,000
(4)	Miscellaneous Equipment	5% SUBTOTAL MPE		$11,050
	TOTAL MPE			$232,050
(5)	Installation of MPE	15% MPE		$34,808
(6)	Instrumentation and Controls	15% MPE		$34,808
(7)	Piping	10% MPE		$23,205
(8)	Electrical	15% MPE		$34,808
(9)	Site Preparation	10% MPE		$23,205
(10)	Utilities	10% MPE		$23,205
(11)	Buildings and Services	5% MPE		$11,603
		TOTAL DIRECT COSTS (DC)		$417,690

INDIRECT COSTS

(12)	Engineering, Supervision	5% DC		$20,885
(13)	Construction Expenses	5% DC		$20,885
(14)	Contractor's Overhead and Profit	10% DC		$41,769
		TOTAL INDIRECT COSTS (IC)		$83,538
(15)	Contingency	30% (DC + IC)		$150,368
		TOTAL CAPITAL COSTS		$651,596

TABLE A-3
CAPITAL/O&M COST ESTIMATE
MEMBRANE SEPARATION ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O&M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$23,205
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (44 kW x $.08/kW-hr x 2,160 hrs)	$7,603
6	Raw Materials	$0
7	Hazardous Waste Disposal	$30,000
8	Insurance 1% of Total Capital	$6,516
9	SUBTOTAL (excluding contractor's fee)	$102,744
10	Contractor's Fee 15% of Labor & maintenance	$8,269
	TOTAL O & M	$111,013

TABLE A-4

CAPITAL/O&M COST ESTIMATE
MEMBRANE SEPARATION ALTERNATIVE WITH WATER TREATMENT

DIRECT COSTS					
	Major Purchased Equipment (MPE)		Quantity	Unit Cost	Total Cost
(1)	Membrane Separation Equipment		1	$200,000	$200,000
	Compressor		1	INCL	
	Vacuum Pump		1	INCL	
	Condenser		1	INCL	
	Membrane Modules		1	INCL	
(2)	10,000 gal. Double Walled Storage Tanks		5	$20,000	$100,000
(3)	Air Stripper		1	$10,000	$10,000
(4)	Storage Tank and Condensate Pumps		4	$1,000	$4,000
(5)	10,000 gal VOC Recovery Tank		1	$20,000	$20,000
		SUBTOTAL MPE			$334,000
(6)	Miscellaneous Equipment	5% SUBTOTAL MPE			$16,700
	TOTAL MPE				$350,700
(7)	Installation of MPE	15% MPE			$52,605
(8)	Instrumentation and Controls	15% MPE			$52,605
(9)	Piping	10% MPE			$35,070
(10)	Electrical	15% MPE			$52,605
(11)	Site Preparation	10% MPE			$35,070
(12)	Utilities	10% MPE			$35,070
(13)	Buildings and Services	5% MPE			$17,535
		TOTAL DIRECT COSTS (DC)			$631,260
INDIRECT COSTS					
(14)	Engineering, Supervision	5% DC			$31,563
(15)	Construction Expenses	5% DC			$31,563
(16)	Contractor's Overhead and Profit	10% DC			$63,126
		TOTAL INDIRECT COSTS (IC)			$126,252
(17)	Contingency	30% (DC + IC)			$227,254
		TOTAL CAPITAL COSTS			$984,766

TABLE A-4
CAPITAL/O&M COST ESTIMATE
MEMBRANE SEPARATION ALTERNATIVE WITH WATER TREATMENT
(Concluded)

Item No.	Description	Quarterly O&M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$35,070
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (44 kW x $.08/kW-hr x 2,160 hrs)	$7,603
6	Raw Materials	$0
7	Hazardous Waste Disposal	$30,000
8	Insurance 1% of Total Capital	$9,848
9	SUBTOTAL (excluding contractor's fee)	$117,941
10	Contractor's Fee 15% of Labor & maintenance	$10,049
	TOTAL O & M	$127,989

TABLE A-5

CAPITAL/O&M COST ESTIMATE
OZONE-UV-GAC ALTERNATIVE

DIRECT COSTS					
	Major Purchased Equipment (MPE)	Quantity		Unit Cost	Total Cost
(1)	Ozone-UV-GAC Unit	1		$285,000	$285,000
(2)	Condensate Pump	1		$1,000	$1,000
(3)	Heat Exchanger (Cooler)	1		$5,000	$5,000
		SUBTOTAL MPE			$291,000
(4)	Miscellaneous Equipment	5% SUBTOTAL MPE			$14,550
	TOTAL MPE				$305,550
(5)	Installation of MPE	5% MPE			$15,278
(6)	Instrumentation and Controls	5% MPE			$15,278
(7)	Piping	10% MPE			$30,555
(8)	Electrical	10% MPE			$30,555
(9)	Site Preparation	5% MPE			$15,278
(10)	Utilities	5% MPE			$15,278
(11)	Buildings and Services	3% MPE			$9,167
		TOTAL DIRECT COSTS (DC)			$436,937
INDIRECT COSTS					
(12)	Engineering, Supervision	5% DC			$21,847
(13)	Construction Expenses	5% DC			$21,847
(14)	Contractor's Overhead and Profit	10% DC			$43,694
		TOTAL INDIRECT COSTS (IC)			$87,387
(15)	Contingency	30% (DC + IC)			$157,297
		TOTAL CAPITAL COSTS			$681,621

TABLE A-5
CAPITAL/O&M COST ESTIMATE
OZONE-UV-GAC ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$30,555
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (14 kW x $.08/kW-hr x 2,160 hrs)	$2,420
6	Raw Materials	$14,000
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$6,816
9	SUBTOTAL (excluding contractor's fee)	$89,211
10	Contractor's Fee 15% of Labor & maintenance	$9,371
	TOTAL O & M	$98,582

TABLE A-6

CAPITAL/O&M COST ESTIMATE
OZONE-UV-GAC ALTERNATIVE WITH WATER TREATMENT

			Quantity	Unit Cost	Total Cost
DIRECT COSTS					
	Major Purchased Equipment (MPE)				
(1)	Ozone-UV-GAC Unit		1	$285,000	$285,000
(2)	Double Walled Caustic Storage Tank		1	$20,000	$20,000
(3)	Heat Exchanger (Cooler)		1	$5,000	$5,000
(4)	Airstripper		1	$10,000	$10,000
(5)	Treated Water/Spent Caustic Storage		5	$20,000	$100,000
		SUBTOTAL MPE			$420,000
(6)	Miscellaneous Equipment	5% SUBTOTAL MPE			$21,000
	TOTAL MPE				$441,000
(7)	Installation of MPE	5% MPE			$22,050
(8)	Instrumentation and Controls	5% MPE			$22,050
(9)	Piping	10% MPE			$44,100
(10)	Electrical	10% MPE			$44,100
(11)	Site Preparation	5% MPE			$22,050
(12)	Utilities	5% MPE			$22,050
(13)	Buildings and Services	3% MPE			$13,230
		TOTAL DIRECT COSTS (DC)			$630,630
INDIRECT COSTS					
(14)	Engineering, Supervision	5% DC			$39,761
(15)	Construction Expenses	5% DC			$39,761
(16)	Contractor's Overhead and Profit	10% DC			$79,522
		TOTAL INDIRECT COSTS (IC)			$159,044
(17)	Contingency	30% (DC + IC)			$236,902
		TOTAL CAPITAL COSTS			$1,026,576

TABLE A-6
CAPITAL/O&M COST ESTIMATE
OZONE-UV-GAC ALTERNATIVE WITH WATER TREATMENT
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$44,100
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (14 kW x $.08/kW-hr x 2,160 hrs)	$2,420
6	Raw Materials	$14,000
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$10,266
9	SUBTOTAL (excluding contractor's fee)	$106,206
10	Contractor's Fee 15% of Labor & maintenance	$11,403
	TOTAL O & M	$117,609

TABLE A-7

CAPITAL/O&M COST ESTIMATE
ADSORPTION/CONDENSATION (PURUS) ALTERNATIVE

DIRECT COSTS

	Major Purchased Equipment (MPE)		Quantity	Unit Cost	Total Cost
(1)	Adsorption/Condensation Unit (PURUS)		1	$300,000	$300,000
(2)	VOC Recovery Tank (Double Walled)		1	$20,000	$20,000
(3)	High Volume Condenser		1	$16,000	$16,000
(4)	Condensate and VOC pumps		2	$1,000	$2,000
		SUBTOTAL MPE			$338,000
(5)	Miscellaneous Equipment	5% SUBTOTAL MPE			$16,900
	TOTAL MPE				$354,900
(6)	Installation of MPE	5% MPE			$17,745
(7)	Instrumentation and Controls	5% MPE			$17,745
(8)	Piping	10% MPE			$35,490
(9)	Electrical	10% MPE			$35,490
(10)	Site Preparation	5% MPE			$17,745
(11)	Utilities	5% MPE			$17,745
(12)	Buildings and Services	5% MPE			$17,745
		TOTAL DIRECT COSTS (DC)			$514,605

INDIRECT COSTS

(13)	Engineering, Supervision	5% DC	$25,730
(14)	Construction Expenses	5% DC	$25,730
(15)	Contractor's Overhead and Profit	10% DC	$51,461
		TOTAL INDIRECT COSTS (IC)	$102,921
(16)	Contingency	30% (DC + IC)	$185,258
		TOTAL CAPITAL COSTS	$802,784

TABLE A-7
CAPITAL/O&M COST ESTIMATE
ADSORPTION/CONDENSATION (PURUS) ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$35,490
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (20.5 kW x $.08/kW-hr x 2160 hr)	$3,550
6	Raw Materials	$0
7	Hazardous Waste Disposal	$30,000
8	Insurance 1% of Total Capital	$8,028
9	SUBTOTAL (excluding contractor's fee)	$112,488
10	Contractor's Fee 15% of Labor & maintenance	$10,112
	TOTAL O & M	$122,599

TABLE A-8

CAPITAL/O&M COST ESTIMATE
ADSORPTION/CONDENSATION (PURUS) ALTERNATIVE
WITH WATER TREATMENT

DIRECT COSTS					
	Major Purchased Equipment (MPE)	Quantity		Unit Cost	Total Cost
(1)	Adsorption/Condensation Unit (PURUS)	1		$300,000	$300,000
(2)	VOC Recovery Tank (Double Walled)	1		$20,000	$20,000
(3)	High Volume Condenser	1		$16,000	$16,000
(4)	Condensate and VOC pumps	4		$1,000	$4,000
(5)	Air Stripper	1		$10,000	$10,000
(6)	Condensate Storage Tanks	5		$20,000	$100,000
		SUBTOTAL MPE			$450,000
(7)	Miscellaneous Equipment	5% SUBTOTAL MPE			$22,500
	TOTAL MPE				$472,500
(8)	Installation of MPE	5% MPE			$23,625
(9)	Instrumentation and Controls	5% MPE			$23,625
(10)	Piping	10% MPE			$47,250
(11)	Electrical	10% MPE			$47,250
(12)	Site Preparation	5% MPE			$23,625
(13)	Utilities	5% MPE			$23,625
(14)	Buildings and Services	5% MPE			$23,625
		TOTAL DIRECT COSTS (DC)			$685,125
INDIRECT COSTS					
(15)	Engineering, Supervision	5% DC			$34,256
(16)	Construction Expenses	5% DC			$34,256
(17)	Contractor's Overhead and Profit	10% DC			$68,513
		TOTAL INDIRECT COSTS (IC)			$137,025
(18)	Contingency	30% (DC + IC)			$246,645
		TOTAL CAPITAL COSTS			$1,068,795

TABLE A-8
CAPITAL/O&M COST ESTIMATE
ADSORPTION/CONDENSATION (PURUS) ALTERNATIVE
WITH WATER TREATMENT
(Concluded)

Item No.	Description		Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)		$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)		$3,120
3	Maintenance	10% of MPE	$47,250
4	Environmental & Health Compliance Costs		$3,500
5	Utilities (20.5 kW x $.08/kW-hr x 2160 hr)		$3,550
6	Raw Materials		$0
7	Hazardous Waste Disposal		$30,000
8	Insurance	1% of Total Capital	$10,688
9	SUBTOTAL (excluding contractor's fee)		$126,908
10	Contractor's Fee	15% of Labor & maintenance	$11,876
	TOTAL O & M		$138,783

TABLE A-9

CAPITAL/O&M COST ESTIMATE
CONDENSATION/REFRIGERATION ALTERNATIVE

DIRECT COSTS

			Quantity	Unit Cost	Total Cost
	Major Purchased Equipment (MPE)				
(1)	Condensation Equipment		1	$176,000	$176,000
	Refrigeration Blower		1	INCL	
	Compressor		2	INCL	
	Air Cooled Condenser		1	INCL	
	Fin and Tube Coils		1	INCL	
(2)	Condensate Pump		1	$1,000	$1,000
(3)	10,000 gal VOC Recovery Tank		1	$20,000	$20,000
		SUBTOTAL MPE			$197,000
(4)	Miscellaneous Equipment	5% SUBTOTAL MPE			$9,850
	TOTAL MPE				$206,850
(5)	Installation of MPE	20% MPE			$41,370
(6)	Instrumentation and Controls	15% MPE			$31,028
(7)	Piping	10% MPE			$20,685
(8)	Electrical	10% MPE			$20,685
(9)	Site Preparation	5% MPE			$10,343
(10)	Utilities	10% MPE			$20,685
(11)	Buildings and Services	10% MPE			$20,685
		TOTAL DIRECT COSTS (DC)			$372,330

INDIRECT COSTS

(12)	Engineering, Supervision	5% DC	$18,617
(13)	Construction Expenses	5% DC	$18,617
(14)	Contractor's Overhead and Profit	10% DC	$37,233
		TOTAL INDIRECT COSTS (IC)	$74,466
(15)	Contingency	30% (DC + IC)	$134,039
		TOTAL CAPITAL COSTS	$580,835

TABLE A-9
CAPITAL/O&M COST ESTIMATE
CONDENSATION/REFRIGERATION ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$20,685
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (44 kW x $.08/kW-hr x 2,160 hrs)	$7,603
6	Raw Materials	$0
7	Hazardous Waste Disposal	$30,000
8	Insurance 1% of Total Capital	$5,808
9	SUBTOTAL (excluding contractor's fee)	$99,516
10	Contractor's Fee 15% of Labor & maintenance	$7,891
	TOTAL O & M	$107,407

TABLE A-10

CAPITAL/O&M COST ESTIMATE
CONDENSATION/REFRIGERATION ALTERNATIVE
WITH WATER TREATMENT

DIRECT COSTS				
	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Condensation Equipment	1	$176,000	$176,000
	Refrigeration Blower	1	INCL	
	Compressor	2	INCL	
	Air Cooled Condenser	1	INCL	
	Fin and Tube Coils	1	INCL	
(2)	10,000 gal. Double Walled Storage Tanks	5	$20,000	$100,000
(3)	Air Stripper	1	$10,000	$10,000
(4)	Storage Tank and Condensate Pumps	4	$1,000	$4,000
(5)	10,000 gal VOC Recovery Tank	1	$20,000	$20,000
		SUBTOTAL MPE		$310,000
(6)	Miscellaneous Equipment	5% SUBTOTAL MPE		$15,500
	TOTAL MPE			$325,500
(7)	Installation of MPE	20% MPE		$65,100
(8)	Instrumentation and Controls	15% MPE		$48,825
(9)	Piping	10% MPE		$32,550
(10)	Electrical	10% MPE		$32,550
(11)	Site Preparation	5% MPE		$16,275
(12)	Utilities	10% MPE		$32,550
(13)	Buildings and Services	10% MPE		$32,550
		TOTAL DIRECT COSTS (DC)		$585,900
INDIRECT COSTS				
(14)	Engineering, Supervision	5% DC		$29,295
(15)	Construction Expenses	5% DC		$29,295
(16)	Contractor's Overhead and Profit	10% DC		$58,590
		TOTAL INDIRECT COSTS (IC)		$117,180
(17)	Contingency	30% (DC + IC)		$210,924
		TOTAL CAPITAL COSTS		$914,004

TABLE A-10
CAPITAL/O&M COST ESTIMATE
CONDENSATION/REFRIGERATION ALTERNATIVE
WITH WATER TREATMENT
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$32,550
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (44 kW x $.08/kW-hr x 2,160 hrs)	$7,603
6	Raw Materials	$0
7	Hazardous Waste Disposal	$30,000
8	Insurance 1% of Total Capital	$9,140
9	SUBTOTAL (excluding contractor's fee)	$114,713
10	Contractor's Fee 15% of Labor & maintenance	$9,671
	TOTAL O & M	$124,384

TABLE A-11

CAPITAL/O&M COST ESTIMATE
FLAMELESS THERMAL OXIDATION ALTERNATIVE

DIRECT COSTS				
	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Flameless Thermal Oxidizer (Electric)	1	$380,000	$380,000
(2)	High Volume Condenser	1	$16,000	$16,000
(3)	Condensate Pump	1	$1,000	$1,000
		SUBTOTAL MPE		$397,000
(4)	Miscellaneous Equipment	5% SUBTOTAL MPE		$19,850
	TOTAL MPE			$416,850
(5)	Installation of MPE	15% MPE		$62,528
(6)	Instrumentation and Controls	10% MPE		$41,685
(7)	Piping	10% MPE		$41,685
(8)	Electrical	10% MPE		$41,685
(9)	Site Preparation	5% MPE		$20,843
(10)	Utilities	5% MPE		$20,843
(11)	Buildings and Services	5% MPE		$20,843
		TOTAL DIRECT COSTS (DC)		$666,960
INDIRECT COSTS				
(12)	Engineering, Supervision	5% DC		$33,348
(13)	Construction Expenses	5% DC		$33,348
(14)	Contractor's Overhead and Profit	10% DC		$66,696
		TOTAL INDIRECT COSTS (IC)		$133,392
(15)	Contingency	30% (DC + IC)		$240,106
		TOTAL CAPITAL COSTS		$1,040,458

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TABLE A-11
CAPITAL/O&M COST ESTIMATE
FLAMELESS THERMAL OXIDATION ALTERNATIVE

(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$41,685
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (45 kW x $.08/kW-hr x 2,160 hrs)	$7,776
6	Raw Materials	$16,800
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$10,405
9	SUBTOTAL (excluding contractor's fee)	$112,086
10	Contractor's Fee 15% of Labor & maintenance	$11,041
	TOTAL O & M	$123,126

TABLE A-12

CAPITAL/O&M COST ESTIMATE
FLAMELESS THERMAL OXIDATION ALTERNATIVE
WITH WATER TREATMENT AND SCRUBBER

DIRECT COSTS				
	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Flameless Thermal Oxidizer (Electric)	1	$380,000	$380,000
(2)	High Volume Condenser	1	$16,000	$16,000
(3)	Condensate Storage Tanks	5	$20,000	$100,000
(4)	10,000 gal Caustic Tank (Double Walled)	1	$20,000	$20,000
(5)	Spent Caustic and Condensate Pumps	4	$1,000	$4,000
(6)	Spent Caustic Storage Tank	1	$20,000	$20,000
(7)	Air Stripper	1	$10,000	$10,000
(8)	pH metering pump and spent caustic neutraliz	1	$5,000	$5,000
		SUBTOTAL MPE		$555,000
(9)	Miscellaneous Equipment	5% SUBTOTAL MPE		$27,750
	TOTAL MPE			$582,750
(10)	Installation of MPE	15% MPE		$87,413
(11)	Instrumentation and Controls	10% MPE		$58,275
(12)	Piping	10% MPE		$58,275
(13)	Electrical	10% MPE		$58,275
(14)	Site Preparation	5% MPE		$29,138
(15)	Utilities	5% MPE		$29,138
(16)	Buildings and Services	5% MPE		$29,138
		TOTAL DIRECT COSTS (DC)		$932,400
INDIRECT COSTS				
(19)	Engineering, Supervision	5% DC		$46,620
(20)	Construction Expenses	5% DC		$46,620
(21)	Contractor's Overhead and Profit	10% DC		$93,240
		TOTAL INDIRECT COSTS (IC)		$186,480
(22)	Contingency	30% (DC + IC)		$335,664
		TOTAL CAPITAL COSTS		$1,454,544

TABLE A-12
CAPITAL/O&M COST ESTIMATE
FLAMELESS THERMAL OXIDATION ALTERNATIVE
WITH WATER TREATMENT AND SCRUBBER
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$58,275
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (45 kW x $.08/kW-hr x 2,160 hrs)	$7,776
6	Raw Materials	$16,800
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$14,545
9	SUBTOTAL (excluding contractor's fee)	$132,816
10	Contractor's Fee 15% of Labor & maintenance	$13,529
	TOTAL O & M	$146,346

TABLE A-13

CAPITAL/O&M COST ESTIMATE
THERMAL OXIDIZER ALTERNATIVE

DIRECT COSTS				
	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Thermal Oxidizer	1	$50,000	$50,000
(2)	Propane Storage Tank	1	$8,000	$8,000
(3)	Condensate Pump	1	$1,000	$1,000
(4)	High Volume Condenser	1	$16,000	$16,000
		SUBTOTAL MPE		$75,000
(5)	Miscellaneous Equipment	5% SUBTOTAL MPE		$3,750
	TOTAL MPE			$78,750
(6)	Installation of MPE	30% MPE		$23,625
(7)	Instrumentation and Controls	15% MPE		$11,813
(8)	Piping	15% MPE		$11,813
(9)	Electrical	15% MPE		$11,813
(10)	Site Preparation	5% MPE		$3,938
(11)	Utilities	10% MPE		$7,875
(12)	Buildings and Services	5% MPE		$3,938
		TOTAL DIRECT COSTS (DC)		$153,563
INDIRECT COSTS				
(13)	Engineering, Supervision	5% DC		$7,678
(14)	Construction Expenses	5% DC		$7,678
(15)	Contractor's Overhead and Profit	10% DC		$15,356
		TOTAL INDIRECT COSTS (IC)		$30,713
(16)	Contingency	30% (DC + IC)		$55,283
		TOTAL CAPITAL COSTS		$239,558

TABLE A-13
CAPITAL/O&M COST ESTIMATE
THERMAL OXIDIZER ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$7,875
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (4 kW x $.08/kW-hr x 2,160 hrs)	$691
6	Raw Materials (propane and caustic)	$24,300
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$2,396
9	SUBTOTAL (excluding contractor's fee)	$70,682
10	Contractor's Fee 15% of Labor & maintenance	$5,969
	TOTAL O & M	$76,651

TABLE A-14

CAPITAL/O&M COST ESTIMATE
THERMAL OXIDIZER ALTERNATIVE
WITH WATER TREATMENT AND SCRUBBER

DIRECT COSTS				
	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Thermal Oxidizer	1	$50,000	$50,000
(2)	Acid Scrubber	1	$30,000	$30,000
(3)	pH metering pump and post-scrubber neutraliz	1	$5,000	$5,000
(4)	Double Walled Caustic Storage Tank	1	$20,000	$20,000
(5)	Spent Caustic Storage Tank	1	$20,000	$20,000
(6)	Propane Storage Tank	1	$8,000	$8,000
(7)	Caustic and Condensate Pumps	4	$1,000	$4,000
(8)	Air Stripper	1	$10,000	$10,000
(9)	Condensate Storage Tanks	5	$20,000	$100,000
(10)	High Volume Condenser	1	$16,000	$16,000
(11)	10,000 gal Water Tank	1	$10,000	$10,000
		SUBTOTAL MPE		$273,000
(12)	Miscellaneous Equipment	5% SUBTOTAL MPE		$13,650
	TOTAL MPE			$286,650
(13)	Installation of MPE	30% MPE		$85,995
(14)	Instrumentation and Controls	15% MPE		$42,998
(15)	Piping	15% MPE		$42,998
(16)	Electrical	15% MPE		$42,998
(17)	Site Preparation	5% MPE		$14,333
(18)	Utilities	10% MPE		$28,665
(19)	Buildings and Services	5% MPE		$14,333
		TOTAL DIRECT COSTS (DC)		$558,968
INDIRECT COSTS				
(20)	Engineering, Supervision	5% DC		$27,948
(21)	Construction Expenses	5% DC		$27,948
(22)	Contractor's Overhead and Profit	10% DC		$55,897
		TOTAL INDIRECT COSTS (IC)		$111,794
(23)	Contingency	30% (DC + IC)		$201,228
		TOTAL CAPITAL COSTS		$871,989

TABLE A-14
CAPITAL/O&M COST ESTIMATE
THERMAL OXIDIZER ALTERNATIVE
WITH WATER TREATMENT AND SCRUBBER
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$28,665
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (4 kW x $.08/kW-hr x 2,160 hrs)	$691
6	Raw Materials (propane and caustic)	$24,300
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$8,720
9	SUBTOTAL (excluding contractor's fee)	$97,796
10	Contractor's Fee 15% of Labor & maintenance	$9,088
	TOTAL O & M	$106,884

TABLE A-15

CAPITAL/O&M COST ESTIMATE
CATALYTIC OXIDIZER ALTERNATIVE

DIRECT COSTS

	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Catalytic Oxidizer Unit	1	$92,725	$92,725
(2)	Propane Storage Tank	1	$8,000	$8,000
(3)	Condensate Pump	1	$1,000	$1,000
(4)	High Volume Condenser	1	$16,000	$16,000
		SUBTOTAL MPE		$117,725
(5)	Miscellaneous Equipment	5% SUBTOTAL MPE		$5,886
	TOTAL MPE			$123,611
(6)	Installation of MPE	20% MPE		$24,722
(7)	Instrumentation and Controls	15% MPE		$18,542
(8)	Piping	15% MPE		$18,542
(9)	Electrical	15% MPE		$18,542
(10)	Site Preparation	10% MPE		$12,361
(11)	Utilities	10% MPE		$12,361
(12)	Buildings and Services	5% MPE		$6,181
		TOTAL DIRECT COSTS (DC)		$234,861

INDIRECT COSTS

(13)	Engineering, Supervision	5% DC	$11,743
(14)	Construction Expenses	5% DC	$11,743
(15)	Contractor's Overhead and Profit	10% DC	$23,486
		TOTAL INDIRECT COSTS (IC)	$46,972
(16)	Contingency	30% (DC + IC)	$84,550
		TOTAL CAPITAL COSTS	$366,384

TABLE A-15
CAPITAL/O&M COST ESTIMATE
CATALYTIC OXIDIZER ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$12,361
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (8 kW x $.08/kW-hr x 2,160 hrs)	$1,382
6	Raw Materials (propane and caustic)	$24,300
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$3,664
9	SUBTOTAL (excluding contractor's fee)	$77,127
10	Contractor's Fee 15% of Labor & maintenance	$6,642
	TOTAL O & M	$83,769

TABLE A-16

CAPITAL/O&M COST ESTIMATE
CATALYTIC OXIDIZER ALTERNATIVE
WITH WATER TREATMENT AND SCRUBBER

DIRECT COSTS				
	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	Catalytic Oxidizer Unit	1	$92,725	$92,725
(2)	Acid Scrubber	1	$50,000	$50,000
(3)	Double Walled Caustic Storage Tank	1	$20,000	$20,000
(4)	Double Walled Spent Caustic Tank	1	$20,000	$20,000
(5)	Propane Storage Tank	1	$8,000	$8,000
(6)	pH metering pump and spent caustic neutraliz	1	$5,000	$5,000
(7)	High Volume Condenser	1	$5,000	$5,000
(8)	Condensate Storage Tanks	5	$20,000	$100,000
(9)	Caustic and Condensate Pumps	4	$1,000	$4,000
(10)	Air Stripper	1	$10,000	$10,000
(11)	10,000 gal Water Tank	1	$10,000	$10,000
		SUBTOTAL MPE		$324,725
(12)	Miscellaneous Equipment	5% SUBTOTAL MPE		$16,236
	TOTAL MPE			$340,961
(13)	Installation of MPE	20% MPE		$68,192
(14)	Instrumentation and Controls	15% MPE		$51,144
(15)	Piping	15% MPE		$51,144
(16)	Electrical	15% MPE		$51,144
(17)	Site Preparation	10% MPE		$34,096
(18)	Utilities	10% MPE		$34,096
(19)	Buildings and Services	5% MPE		$17,048
		TOTAL DIRECT COSTS (DC)		$647,826
INDIRECT COSTS				
(20)	Engineering, Supervision	5% DC		$32,391
(21)	Construction Expenses	5% DC		$32,391
(22)	Contractor's Overhead and Profit	10% DC		$64,783
		TOTAL INDIRECT COSTS (IC)		$129,565
(23)	Contingency	30% (DC + IC)		$233,217
		TOTAL CAPITAL COSTS		$1,010,609

TABLE A-16
CAPITAL/O&M COST ESTIMATE
CATALYTIC OXIDIZER ALTERNATIVE
WITH WATER TREATMENT AND SCRUBBER
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$34,096
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (8 kW x $.08/kW-hr x 2,160 hrs)	$1,382
6	Raw Materials (propane and caustic)	$24,300
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$10,106
9	SUBTOTAL (excluding contractor's fee)	$105,304
10	Contractor's Fee 15% of Labor & maintenance	$9,902
	TOTAL O & M	$115,207

TABLE A-17

CAPITAL/O&M COST ESTIMATE
HIGH ENERGY CORONA ALTERNATIVE

DIRECT COSTS					
	Major Purchased Equipment (MPE)		Quantity	Unit Cost	Total Cost
(1)	High Energy Corona System		1	$43,000	$43,000
(2)	Power supply, skid, and instrumentation		1	$25,500	$25,500
(3)	High Volume Condenser		1	$16,000	$16,000
(4)	Condensate Pump		1	$1,000	$1,000
		SUBTOTAL MPE			$85,500
(5)	Miscellaneous Equipment	5% SUBTOTAL MPE			$4,275
		TOTAL MPE			$89,775
(6)	Installation of MPE	20% MPE			$17,955
(7)	Instrumentation and Controls	15% MPE			$13,466
(8)	Piping	10% MPE			$8,978
(9)	Electrical	10% MPE			$8,978
(10)	Site Preparation	10% MPE			$8,978
(11)	Utilities	10% MPE			$8,978
(12)	Buildings and Services	5% MPE			$4,489
		TOTAL DIRECT COSTS (DC)			$161,595
INDIRECT COSTS					
(13)	Engineering, Supervision	5% DC			$8,080
(14)	Construction Expenses	5% DC			$8,080
(15)	Contractor's Overhead and Profit	10% DC			$16,160
		TOTAL INDIRECT COSTS (IC)			$32,319
(16)	Contingency	30% (DC + IC)			$58,174
		TOTAL CAPITAL COSTS			$252,088

TABLE A-17
CAPITAL/O&M COST ESTIMATE
HIGH ENERGY CORONA ALTERNATIVE
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$8,978
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (14 kW x $.08/kW-hr x 2,160 hrs)	$2,420
6	Raw Materials (caustic)	$16,800
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$2,521
9	SUBTOTAL (excluding contractor's fee)	$66,138
10	Contractor's Fee 15% of Labor & maintenance	$6,135
	TOTAL O & M	$72,273

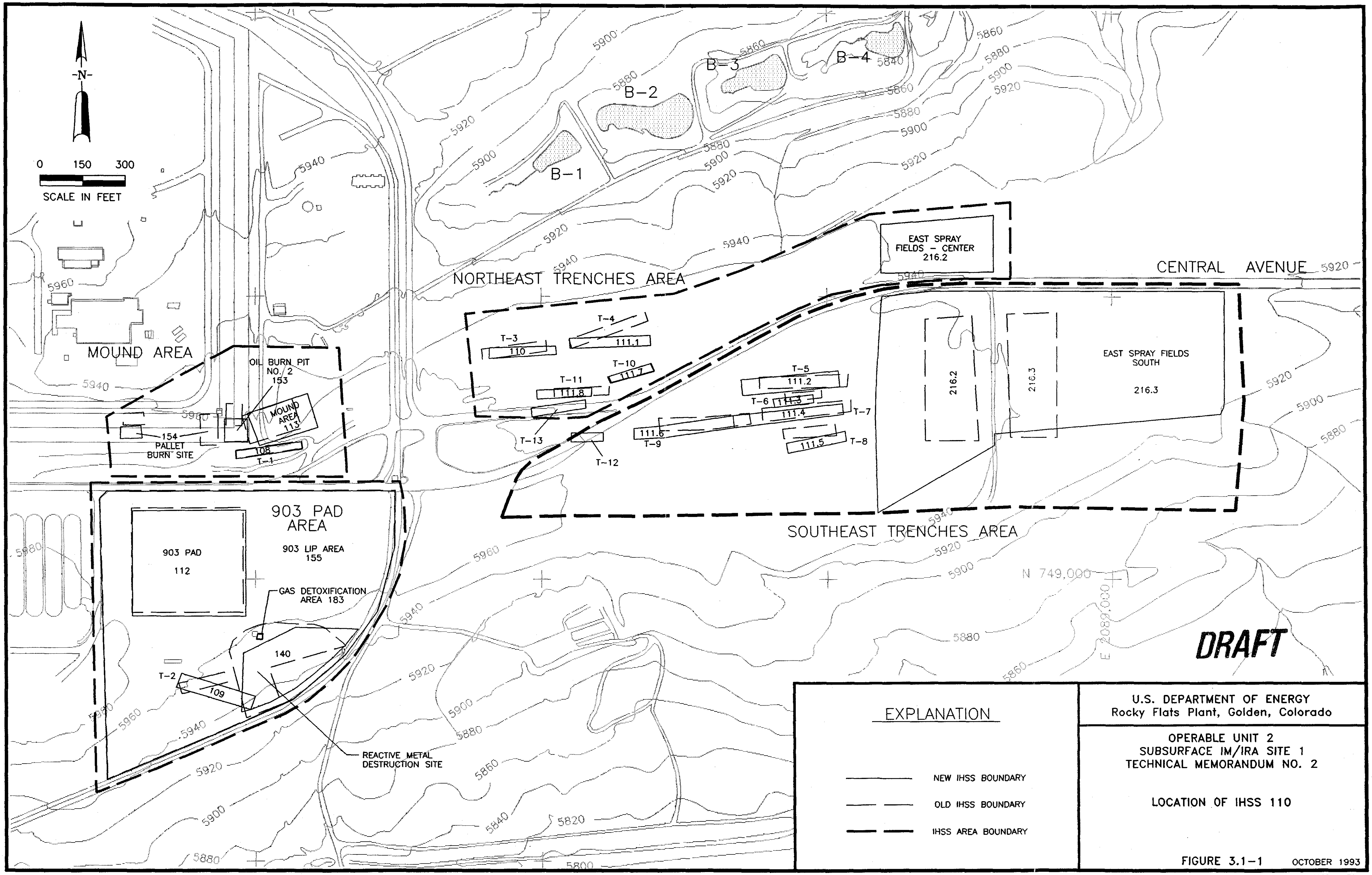
TABLE A-18

CAPITAL/O&M COST ESTIMATE
HIGH ENERGY CORONA ALTERNATIVE
WITH WATER TREATMENT AND SCRUBBER

DIRECT COSTS				
	Major Purchased Equipment (MPE)	Quantity	Unit Cost	Total Cost
(1)	High Energy Corona System	1	$43,000	$43,000
(2)	Acid Scrubber	1	$14,000	$14,000
(3)	Double Walled Caustic Storage Tank	1	$20,000	$20,000
(4)	Power supply, skid, and instrumentation	1	$25,500	$25,500
(5)	Double Walled Spent Caustic Storage Tank	1	$20,000	$20,000
(6)	High Volume Condenser	1	$5,000	$5,000
(7)	Caustic and Condensate Pumps	4	$1,000	$4,000
(8)	Condensate Storage Tanks	5	$20,000	$100,000
(9)	Air Stripper	1	$10,000	$10,000
(10)	pH meter and caustic neutralizer	1	$5,000	$5,000
(11)	10,000 gal Water Tank	1	$10,000	$10,000
		SUBTOTAL MPE		$256,500
(12)	Miscellaneous Equipment	5% SUBTOTAL MPE		$12,825
	TOTAL MPE			$269,325
(13)	Installation of MPE	20% MPE		$53,865
(14)	Instrumentation and Controls	15% MPE		$40,399
(15)	Piping	10% MPE		$26,933
(16)	Electrical	10% MPE		$26,933
(17)	Site Preparation	10% MPE		$26,933
(18)	Utilities	10% MPE		$26,933
(19)	Buildings and Services	5% MPE		$13,466
		TOTAL DIRECT COSTS (DC)		$484,785
INDIRECT COSTS				
(20)	Engineering, Supervision	5% DC		$24,239
(21)	Construction Expenses	5% DC		$24,239
(22)	Contractor's Overhead and Profit	10% DC		$48,479
		TOTAL INDIRECT COSTS (IC)		$96,957
(23)	Contingency	30% (DC + IC)		$174,523
		TOTAL CAPITAL COSTS		$756,265

TABLE A-18
CAPITAL/O&M COST ESTIMATE
HIGH ENERGY CORONA ALTERNATIVE
WITH WATER TREATMENT AND SCRUBBER
(Concluded)

Item No.	Description	Quarterly O & M Estimate
1	Operations Labor (2 people @ $40/hr @ 4 hr/day @ 90 days)	$28,800
2	Supervision Labor ($60/hr @ 4 hr/wk @ 13 wks)	$3,120
3	Maintenance 10% of MPE	$26,933
4	Environmental & Health Compliance Costs	$3,500
5	Utilities (14 kW x $.08/kW-hr x 2,160 hrs)	$2,420
6	Raw Materials (caustic)	$16,800
7	Hazardous Waste Disposal	$0
8	Insurance 1% of Total Capital	$7,563
9	SUBTOTAL (excluding contractor's fee)	$89,135
10	Contractor's Fee 15% of Labor & maintenance	$8,828
	TOTAL O & M	$97,963



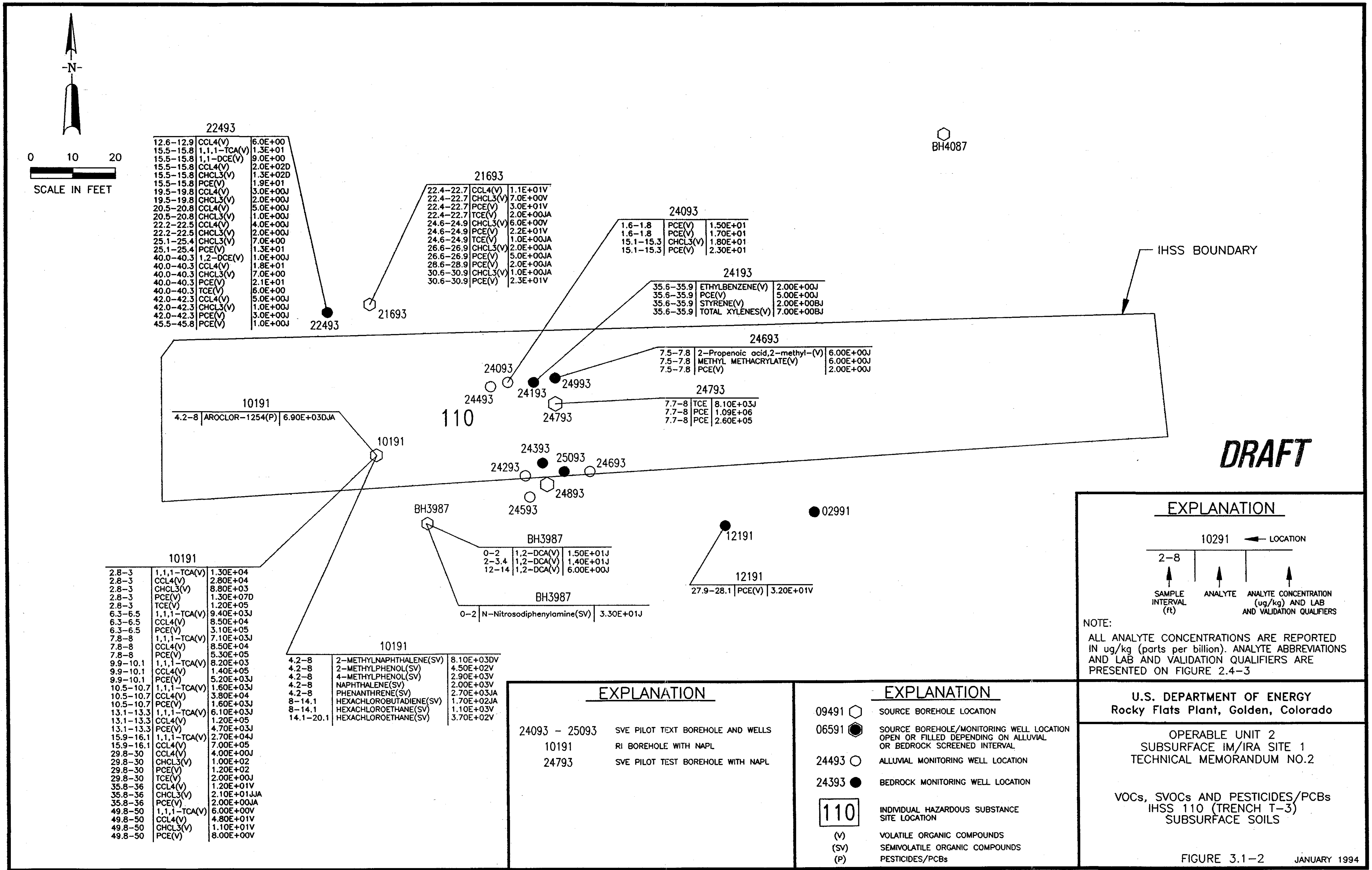
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

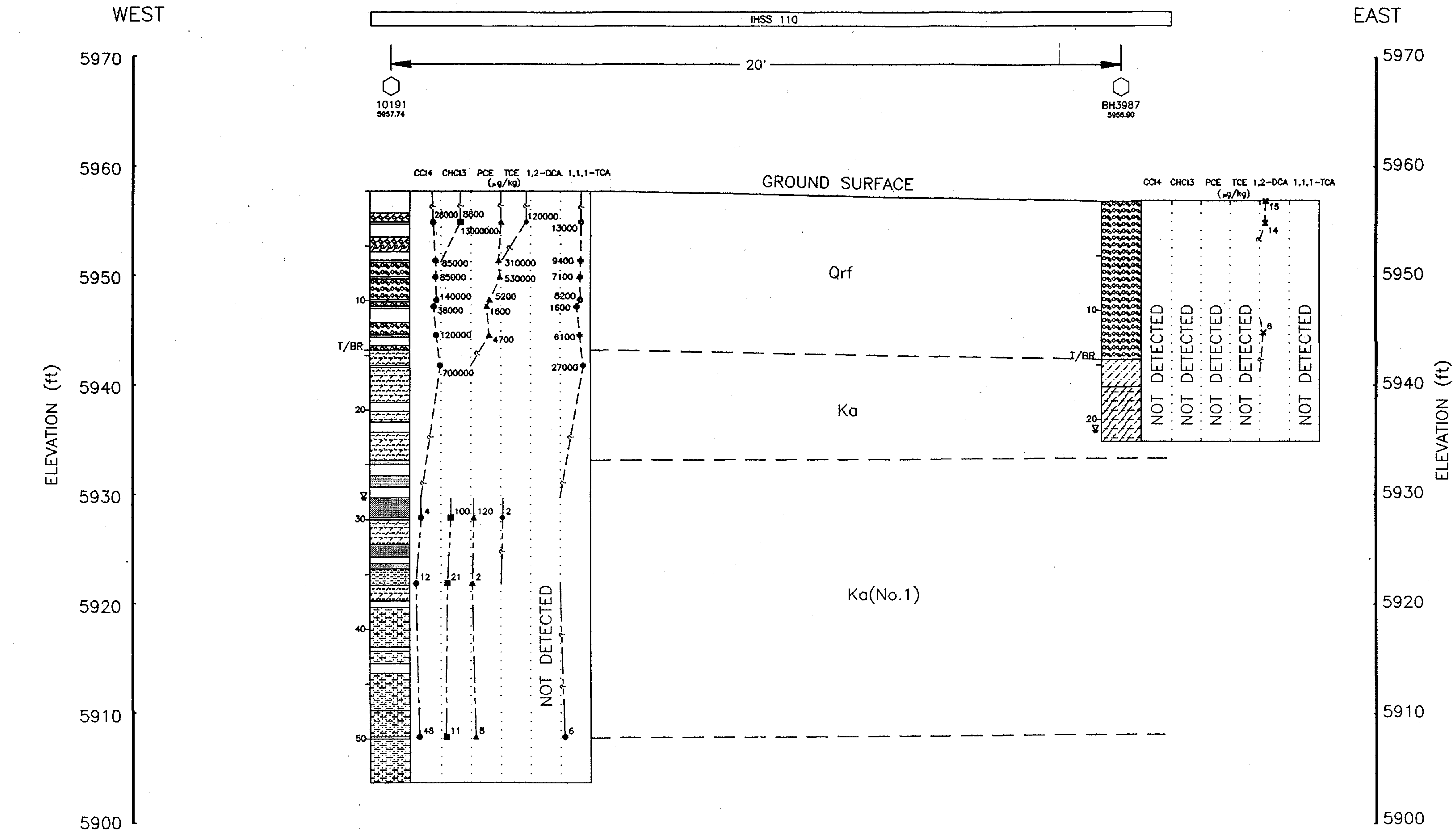
OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO. 2

LOCATION OF IHSS 110

FIGURE 3.1-1 OCTOBER 1993

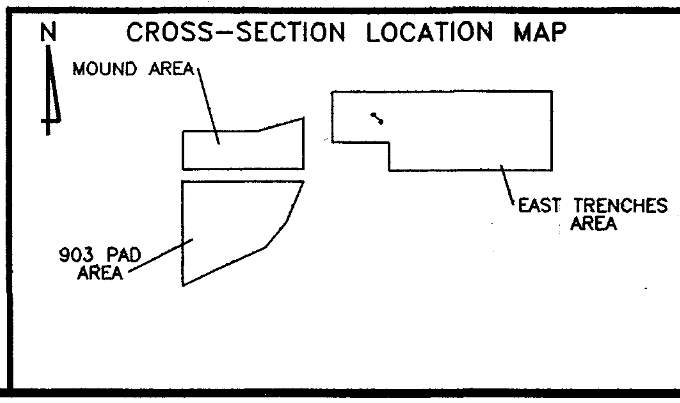
4045023 1=300


-N-
0 10 20
SCALE IN FEET
22493
12.6–12.9 CCL4(V) 6.0E+00
15.5–15.8 1,1,1–TCA(V) 1.3E+01
15.5–15.8 1,1–DCE(V) 9.0E+00
15.5–15.8 CCL4(V) 2.0E+02D
15.5–15.8 CHCL3(V) 1.3E+02D
15.5–15.8 PCE(V) 1.9E+01
19.5–19.8 CCL4(V) 3.0E+00J
19.5–19.8 CHCL3(V) 2.0E+00J
20.5–20.8 CCL4(V) 5.0E+00J
20.5–20.8 CHCL3(V) 1.0E+00J
22.2–22.5 CCL4(V) 4.0E+00J
22.2–22.5 CHCL3(V) 2.0E+00J
25.1–25.4 CHCL3(V) 7.0E+00
25.1–25.4 PCE(V) 1.3E+01
40.0–40.3 1,2–DCE(V) 1.0E+00J
40.0–40.3 CCL4(V) 1.8E+01
40.0–40.3 CHCL3(V) 7.0E+00
40.0–40.3 PCE(V) 2.1E+01
40.0–40.3 TCE(V) 6.0E+00
42.0–42.3 CCL4(V) 5.0E+00J
42.0–42.3 CHCL3(V) 1.0E+00J
42.0–42.3 PCE(V) 3.0E+00J
45.5–45.8 PCE(V) 1.0E+00J
22493
21693
22.4–22.7 CCL4(V) 1.1E+01V
22.4–22.7 CHCL3(V) 7.0E+00V
22.4–22.7 PCE(V) 3.0E+01V
22.4–22.7 TCE(V) 2.0E+00JA
24.6–24.9 CHCL3(V) 6.0E+00V
24.6–24.9 PCE(V) 2.2E+01V
24.6–24.9 TCE(V) 1.0E+00JA
26.6–26.9 CHCL3(V) 2.0E+00JA
26.6–26.9 PCE(V) 5.0E+00JA
28.6–28.9 PCE(V) 2.0E+00JA
30.6–30.9 CHCL3(V) 1.0E+00JA
30.6–30.9 PCE(V) 2.3E+01V
21693
24093
1.6–1.8 PCE(V) 1.50E+01
1.6–1.8 PCE(V) 1.70E+01
15.1–15.3 CHCL3(V) 1.80E+01
15.1–15.3 PCE(V) 2.30E+01
BH4087
IHSS BOUNDARY
24193
35.6–35.9 ETHYLBENZENE(V) 2.00E+00J
35.6–35.9 PCE(V) 5.00E+00J
35.6–35.9 STYRENE(V) 2.00E+00BJ
35.6–35.9 TOTAL XYLENES(V) 7.00E+00BJ
24693
7.5–7.8 2–Propenoic acid,2–methyl–(V) 6.00E+00J
7.5–7.8 METHYL METHACRYLATE(V) 6.00E+00J
7.5–7.8 PCE(V) 2.00E+00J
24093
24493
24193
24993
24793
7.7–8 TCE 8.10E+03J
7.7–8 PCE 1.09E+06
7.7–8 PCE 2.60E+05
24793
110
10191
4.2–8 AROCLOR–1254(P) 6.90E+03DJA
10191
24393
25093
24693
24293
24893
24593
DRAFT
BH3987
02991
12191
BH3987
0–2 1,2–DCA(V) 1.50E+01J
2–3.4 1,2–DCA(V) 1.40E+01J
12–14 1,2–DCA(V) 6.00E+00J
12191
27.9–28.1 PCE(V) 3.20E+01V
BH3987
0–2 N–Nitrosodiphenylamine(SV) 3.30E+01J
10191
2.8–3 1,1,1–TCA(V) 1.30E+04
2.8–3 CCL4(V) 2.80E+04
2.8–3 CHCL3(V) 8.80E+03
2.8–3 PCE(V) 1.30E+07D
2.8–3 TCE(V) 1.20E+05
6.3–6.5 1,1,1–TCA(V) 9.40E+03J
6.3–6.5 CCL4(V) 8.50E+04
6.3–6.5 PCE(V) 3.10E+05
7.8–8 1,1,1–TCA(V) 7.10E+03J
7.8–8 CCL4(V) 8.50E+04
7.8–8 PCE(V) 5.30E+05
9.9–10.1 1,1,1–TCA(V) 8.20E+03
9.9–10.1 CCL4(V) 1.40E+05
9.9–10.1 PCE(V) 5.20E+03J
10.5–10.7 1,1,1–TCA(V) 1.60E+03J
10.5–10.7 CCL4(V) 3.80E+04
10.5–10.7 PCE(V) 1.60E+03J
13.1–13.3 1,1,1–TCA(V) 6.10E+03J
13.1–13.3 CCL4(V) 1.20E+05
13.1–13.3 PCE(V) 4.70E+03J
15.9–16.1 1,1,1–TCA(V) 2.70E+04J
15.9–16.1 CCL4(V) 7.00E+05
29.8–30 CCL4(V) 4.00E+00J
29.8–30 CHCL3(V) 1.00E+02
29.8–30 PCE(V) 1.20E+02
29.8–30 TCE(V) 2.00E+00J
35.8–36 CCL4(V) 1.20E+01V
35.8–36 CHCL3(V) 2.10E+01JJA
35.8–36 PCE(V) 2.00E+00JA
49.8–50 1,1,1–TCA(V) 6.00E+00V
49.8–50 CCL4(V) 4.80E+01V
49.8–50 CHCL3(V) 1.10E+01V
49.8–50 PCE(V) 8.00E+00V
10191
4.2–8 2–METHYLNAPHTHALENE(SV) 8.10E+03DV
4.2–8 2–METHYLPHENOL(SV) 4.50E+02V
4.2–8 4–METHYLPHENOL(SV) 2.90E+03V
4.2–8 NAPHTHALENE(SV) 2.00E+03V
4.2–8 PHENANTHRENE(SV) 2.70E+03JA
8–14.1 HEXACHLOROBUTADIENE(SV) 1.70E+02JA
8–14.1 HEXACHLOROETHANE(SV) 1.10E+03V
14.1–20.1 HEXACHLOROETHANE(SV) 3.70E+02V
EXPLANATION
24093 – 25093 SVE PILOT TEXT BOREHOLE AND WELLS
10191 RI BOREHOLE WITH NAPL
24793 SVE PILOT TEST BOREHOLE WITH NAPL
EXPLANATION
09491 SOURCE BOREHOLE LOCATION
06591 SOURCE BOREHOLE/MONITORING WELL LOCATION OPEN OR FILLED DEPENDING ON ALLUVIAL OR BEDROCK SCREENED INTERVAL
24493 ALLUVIAL MONITORING WELL LOCATION
24393 BEDROCK MONITORING WELL LOCATION
110 INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATION
(V) VOLATILE ORGANIC COMPOUNDS
(SV) SEMIVOLATILE ORGANIC COMPOUNDS
(P) PESTICIDES/PCBs
EXPLANATION
10291 LOCATION
2–8
SAMPLE INTERVAL (ft)
ANALYTE
ANALYTE CONCENTRATION (ug/kg) AND LAB AND VALIDATION QUALIFIERS
NOTE:
ALL ANALYTE CONCENTRATIONS ARE REPORTED IN ug/kg (parts per billion). ANALYTE ABBREVIATIONS AND LAB AND VALIDATION QUALIFIERS ARE PRESENTED ON FIGURE 2.4–3
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2
VOCs, SVOCs AND PESTICIDES/PCBs
IHSS 110 (TRENCH T–3)
SUBSURFACE SOILS
FIGURE 3.1–2
JANUARY 1994
4045003 1=20



NOTE: HORIZONTAL DISTANCE NOT TO SCALE.

VERTICAL SCALE IN FEET: 0 – 10



EXPLANATION

T/BR = TOP OF BEDROCK

⬡ = LOCATION SYMBOL

3486 = LOCATION NAME

5912.00 = GROUND SURFACE ELEVATION (ft)

EACH CHEMICAL IS PLOTTED ON A LOGARITHMIC SCALE (INCREASING TO RIGHT) FROM 1 TO 1,000,000 (µg/kg). DATA POINT REPRESENTS TOP OF SAMPLING INTERVAL.

DRAFT

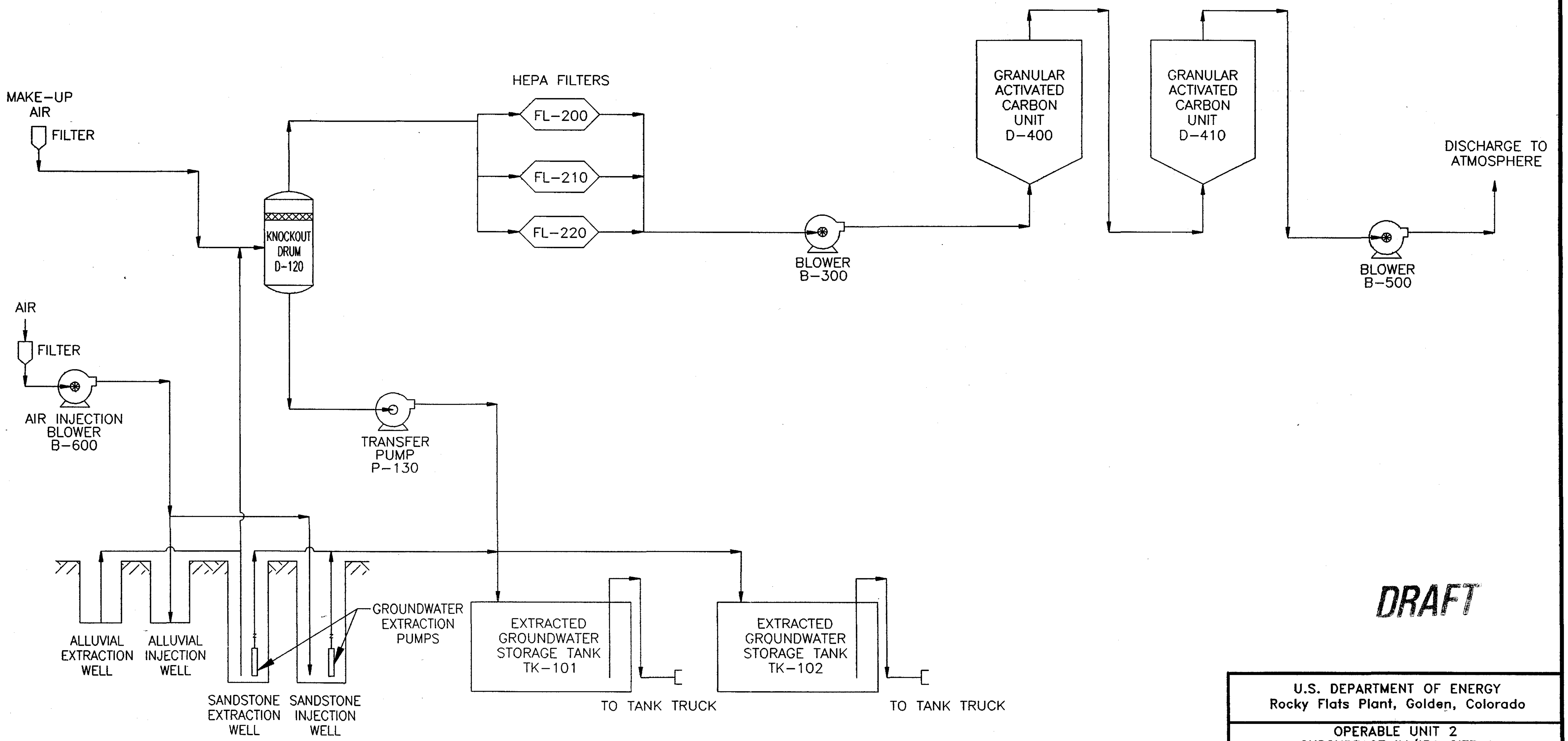
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2

SOURCE BOREHOLE
CROSS-SECTION
IHSS 110 (TRENCH T-3)

FIGURE 3.1-3 JANUARY 1994

4045001 1=1



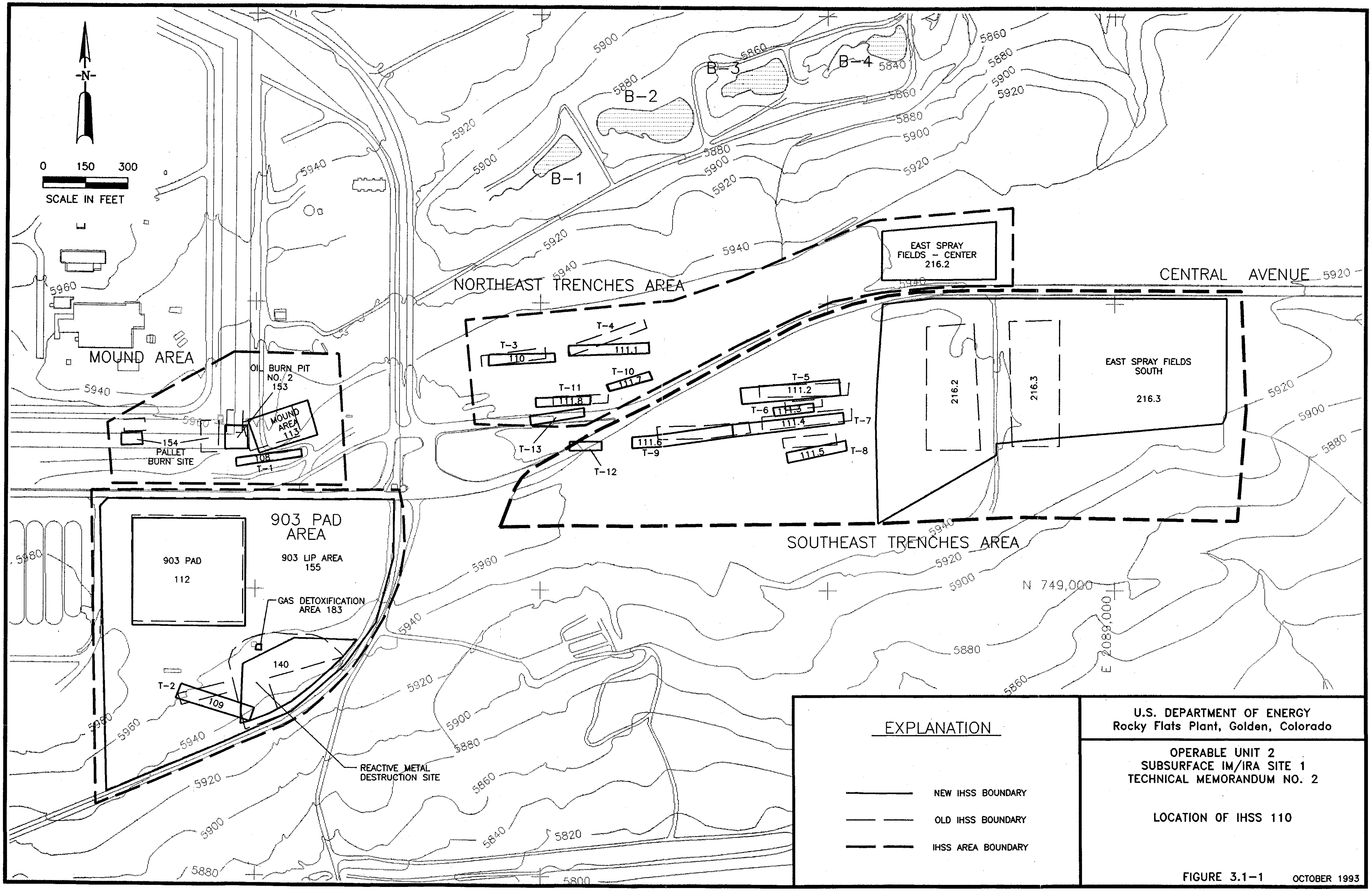
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO. 2

SOIL VAPOR EXTRACTION
PROCESS FLOW DIAGRAM

FIGURE 4.2-1 JANUARY 1994

4045006 1=1



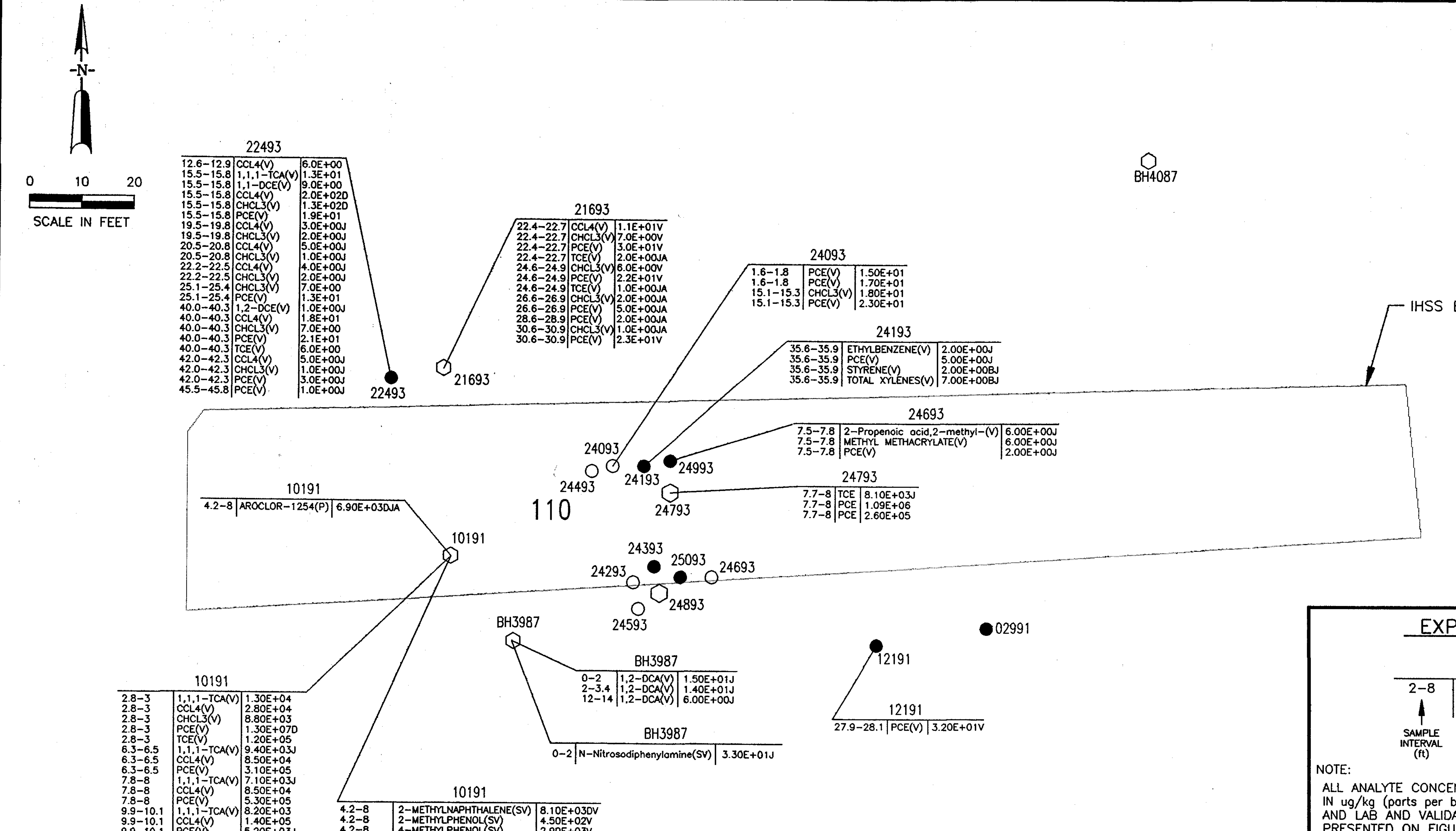
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO. 2

LOCATION OF IHSS 110

FIGURE 3.1-1 OCTOBER 1993

4045023 1=300



22493

12.6–12.9	CCL4(V)	6.0E+00
15.5–15.8	1,1,1–TCA(V)	1.3E+01
15.5–15.8	1,1–DCE(V)	9.0E+00
15.5–15.8	CCL4(V)	2.0E+02D
15.5–15.8	CHCL3(V)	1.3E+02D
15.5–15.8	PCE(V)	1.9E+01
19.5–19.8	CCL4(V)	3.0E+00J
19.5–19.8	CHCL3(V)	2.0E+00J
20.5–20.8	CCL4(V)	5.0E+00J
20.5–20.8	CHCL3(V)	1.0E+00J
22.2–22.5	CCL4(V)	4.0E+00J
22.2–22.5	CHCL3(V)	2.0E+00J
25.1–25.4	CHCL3(V)	7.0E+00
25.1–25.4	PCE(V)	1.3E+01
40.0–40.3	1,2–DCE(V)	1.0E+00J
40.0–40.3	CCL4(V)	1.8E+01
40.0–40.3	CHCL3(V)	7.0E+00
40.0–40.3	PCE(V)	2.1E+01
40.0–40.3	TCE(V)	6.0E+00
42.0–42.3	CCL4(V)	5.0E+00J
42.0–42.3	CHCL3(V)	1.0E+00J
42.0–42.3	PCE(V)	3.0E+00J
45.5–45.8	PCE(V)	1.0E+00J

21693

22.4–22.7	CCL4(V)	1.1E+01V
22.4–22.7	CHCL3(V)	7.0E+00V
22.4–22.7	PCE(V)	3.0E+01V
22.4–22.7	TCE(V)	2.0E+00JA
24.6–24.9	CHCL3(V)	6.0E+00V
24.6–24.9	PCE(V)	2.2E+01V
24.6–24.9	TCE(V)	1.0E+00JA
26.6–26.9	CHCL3(V)	2.0E+00JA
26.6–26.9	PCE(V)	5.0E+00JA
28.6–28.9	PCE(V)	2.0E+00JA
30.6–30.9	CHCL3(V)	1.0E+00JA
30.6–30.9	PCE(V)	2.3E+01V

24093

1.6–1.8	PCE(V)	1.50E+01
1.6–1.8	PCE(V)	1.70E+01
15.1–15.3	CHCL3(V)	1.80E+01
15.1–15.3	PCE(V)	2.30E+01

24193

35.6–35.9	ETHYLBENZENE(V)	2.00E+00J
35.6–35.9	PCE(V)	5.00E+00J
35.6–35.9	STYRENE(V)	2.00E+00BJ
35.6–35.9	TOTAL XYLENES(V)	7.00E+00BJ

24693

7.5–7.8	2–Propenoic acid,2–methyl–(V)	6.00E+00J
7.5–7.8	METHYL METHACRYLATE(V)	6.00E+00J
7.5–7.8	PCE(V)	2.00E+00J

24793

7.7–8	TCE	8.10E+03J
7.7–8	PCE	1.09E+06
7.7–8	PCE	2.60E+05

10191

4.2–8	AROCLOR–1254(P)	6.90E+03DJA

10191

2.8–3	1,1,1–TCA(V)	1.30E+04
2.8–3	CCL4(V)	2.80E+04
2.8–3	CHCL3(V)	8.80E+03
2.8–3	PCE(V)	1.30E+07D
2.8–3	TCE(V)	1.20E+05
6.3–6.5	1,1,1–TCA(V)	9.40E+03J
6.3–6.5	CCL4(V)	8.50E+04
6.3–6.5	PCE(V)	3.10E+05
7.8–8	1,1,1–TCA(V)	7.10E+03J
7.8–8	CCL4(V)	8.50E+04
7.8–8	PCE(V)	5.30E+05
9.9–10.1	1,1,1–TCA(V)	8.20E+03
9.9–10.1	CCL4(V)	1.40E+05
9.9–10.1	PCE(V)	5.20E+03J
10.5–10.7	1,1,1–TCA(V)	1.60E+03J
10.5–10.7	CCL4(V)	3.80E+04
10.5–10.7	PCE(V)	1.60E+03J
13.1–13.3	1,1,1–TCA(V)	6.10E+03J
13.1–13.3	CCL4(V)	1.20E+05
13.1–13.3	PCE(V)	4.70E+03J
15.9–16.1	1,1,1–TCA(V)	2.70E+04J
15.9–16.1	CCL4(V)	7.00E+05
29.8–30	CCL4(V)	4.00E+00J
29.8–30	CHCL3(V)	1.00E+02
29.8–30	PCE(V)	1.20E+02
29.8–30	TCE(V)	2.00E+00J
35.8–36	CCL4(V)	1.20E+01V
35.8–36	CHCL3(V)	2.10E+01JJA
35.8–36	PCE(V)	2.00E+00JA
49.8–50	1,1,1–TCA(V)	6.00E+00V
49.8–50	CCL4(V)	4.80E+01V
49.8–50	CHCL3(V)	1.10E+01V
49.8–50	PCE(V)	8.00E+00V

10191

4.2–8	2–METHYLNAPHTHALENE(SV)	8.10E+03DV
4.2–8	2–METHYLPHENOL(SV)	4.50E+02V
4.2–8	4–METHYLPHENOL(SV)	2.90E+03V
4.2–8	NAPHTHALENE(SV)	2.00E+03V
4.2–8	PHENANTHRENE(SV)	2.70E+03JA
8–14.1	HEXACHLOROBUTADIENE(SV)	1.70E+02JA
8–14.1	HEXACHLOROETHANE(SV)	1.10E+03V
14.1–20.1	HEXACHLOROETHANE(SV)	3.70E+02V

BH3987

0–2	1,2–DCA(V)	1.50E+01J
2–3.4	1,2–DCA(V)	1.40E+01J
12–14	1,2–DCA(V)	6.00E+00J

BH3987

0–2	N–Nitrosodiphenylamine(SV)	3.30E+01J

12191

27.9–28.1	PCE(V)	3.20E+01V

EXPLANATION

24093 – 25093	SVE PILOT TEXT BOREHOLE AND WELLS
10191	RI BOREHOLE WITH NAPL
24793	SVE PILOT TEST BOREHOLE WITH NAPL

EXPLANATION

09491	SOURCE BOREHOLE LOCATION
06591	SOURCE BOREHOLE/MONITORING WELL LOCATION OPEN OR FILLED DEPENDING ON ALLUVIAL OR BEDROCK SCREENED INTERVAL
24493	ALLUVIAL MONITORING WELL LOCATION
24393	BEDROCK MONITORING WELL LOCATION
110	INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATION
(V)	VOLATILE ORGANIC COMPOUNDS
(SV)	SEMIVOLATILE ORGANIC COMPOUNDS
(P)	PESTICIDES/PCBs

EXPLANATION

10291 ← LOCATION

2-8

SAMPLE INTERVAL (ft) | ANALYTE | ANALYTE CONCENTRATION (ug/kg) AND LAB AND VALIDATION QUALIFIERS

NOTE:

ALL ANALYTE CONCENTRATIONS ARE REPORTED IN ug/kg (parts per billion). ANALYTE ABBREVIATIONS AND LAB AND VALIDATION QUALIFIERS ARE PRESENTED ON FIGURE 2.4-3

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

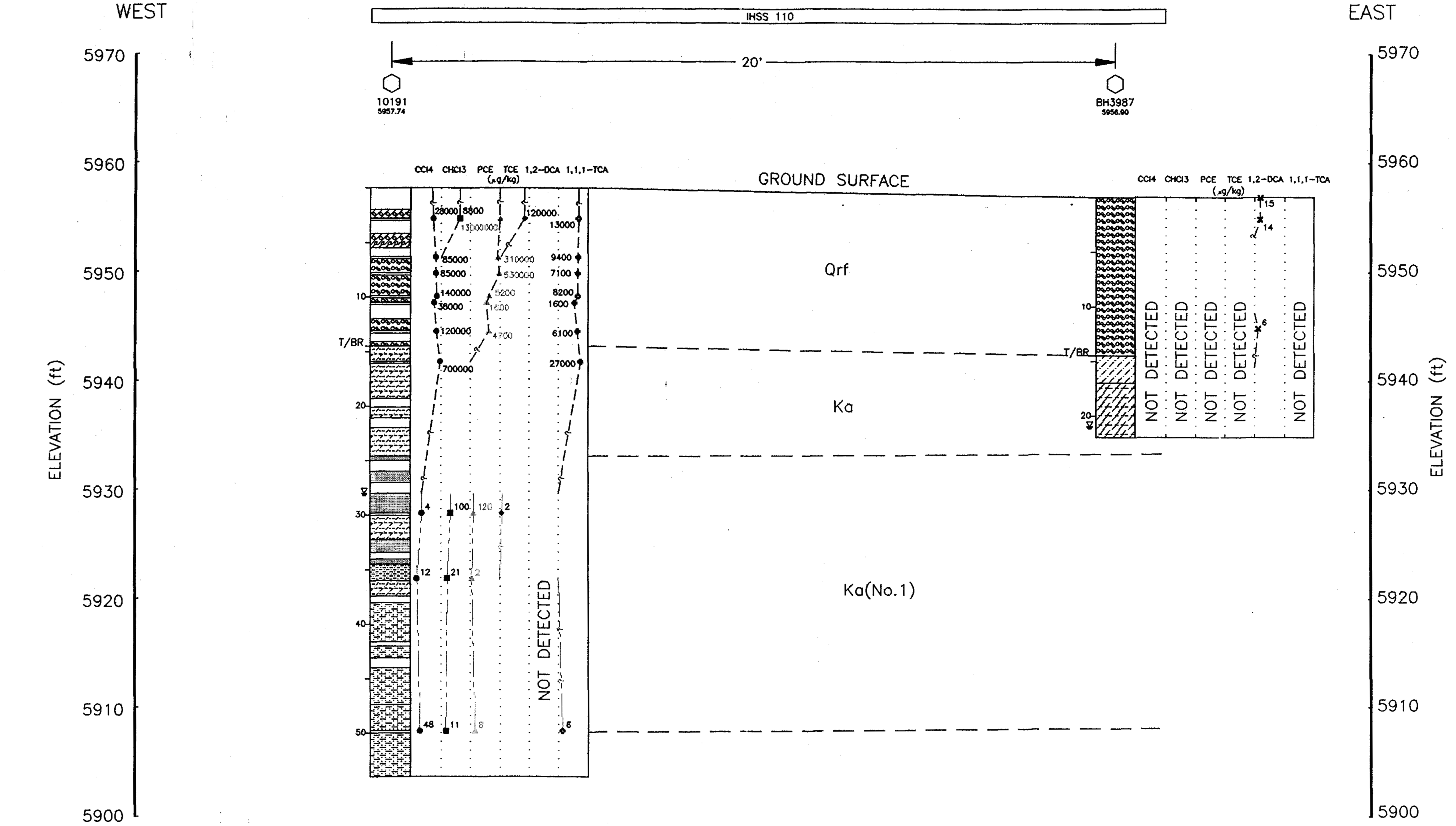
OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2

VOCs, SVOCs AND PESTICIDES/PCBs
IHSS 110 (TRENCH T-3)
SUBSURFACE SOILS

FIGURE 3.1-2

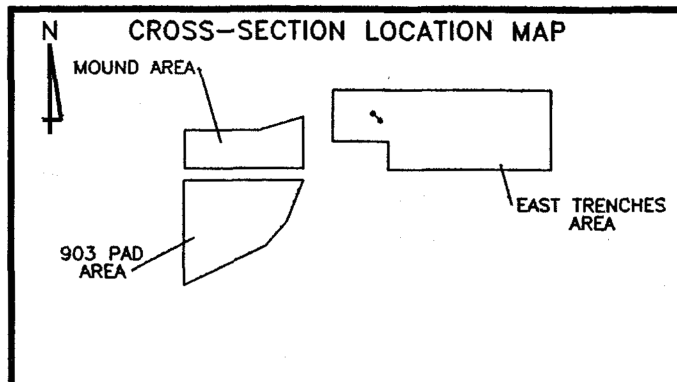
JANUARY 1994

4045003 1=20



0
VERTICAL
SCALE IN FEET
10

NOTE: HORIZONTAL DISTANCE NOT TO SCALE.



EXPLANATION

T/BR = TOP OF BEDROCK
= LOCATION SYMBOL
3486 = LOCATION NAME
5912.00 = GROUND SURFACE ELEVATION (ft)

EACH CHEMICAL IS PLOTTED ON A LOGARITHMIC SCALE (INCREASING TO RIGHT) FROM 1 TO 1,000,000 (µg/kg). DATA POINT REPRESENTS TOP OF SAMPLING INTERVAL.

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Rocky Flats Plant, Golden, Colorado

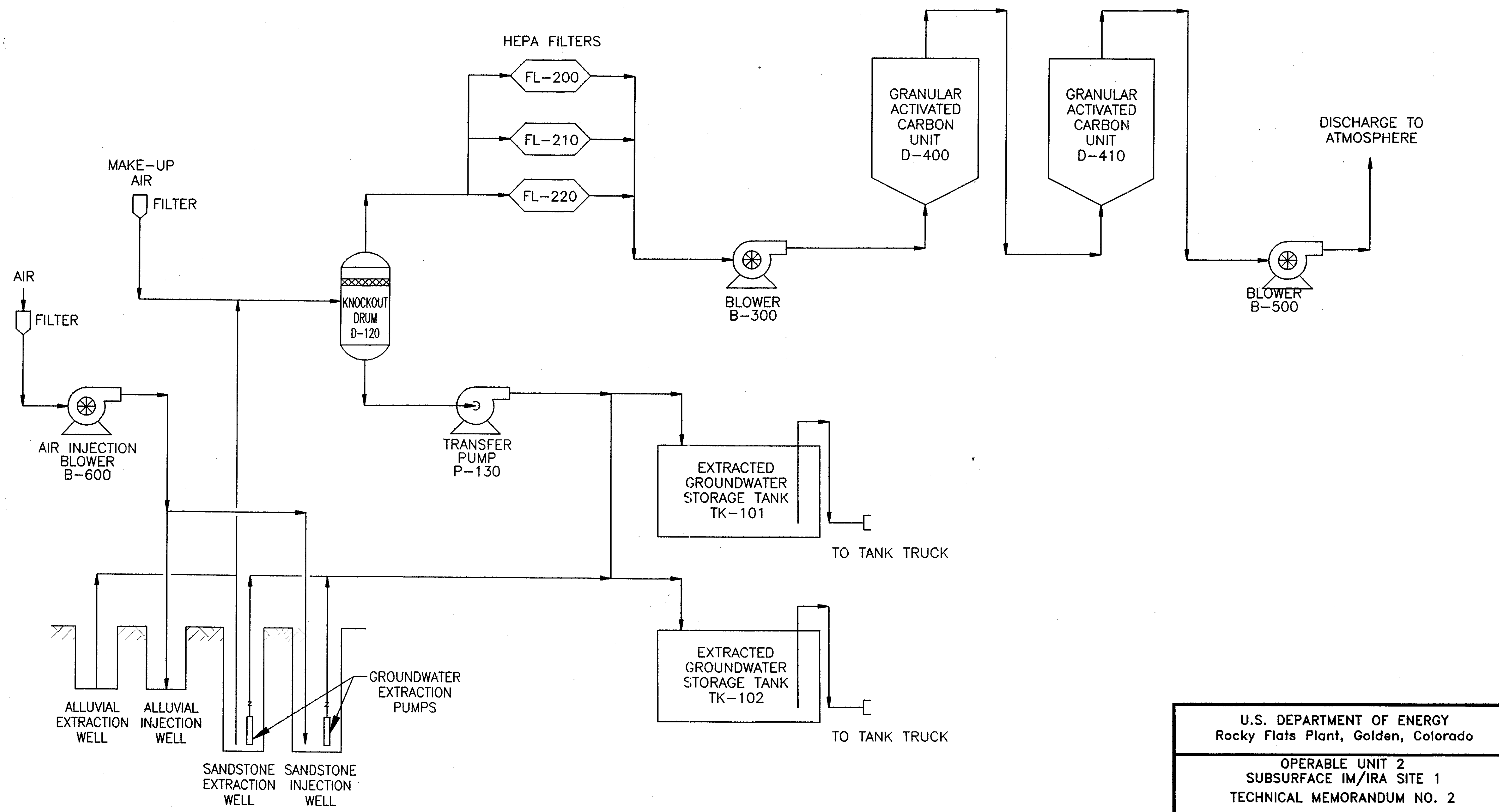
OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO.2

SOURCE BOREHOLE CROSS-SECTION IHSS 110 (TRENCH T-3)

FIGURE 3.1-3

JANUARY 1994

4045001 1=1



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Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO. 2

SOIL VAPOR EXTRACTION
PROCESS FLOW DIAGRAM

FIGURE 4.1-1 JANUARY 1994

4045006 1=1

TABLE 6.2-1
ALTERNATIVE COMPARISON

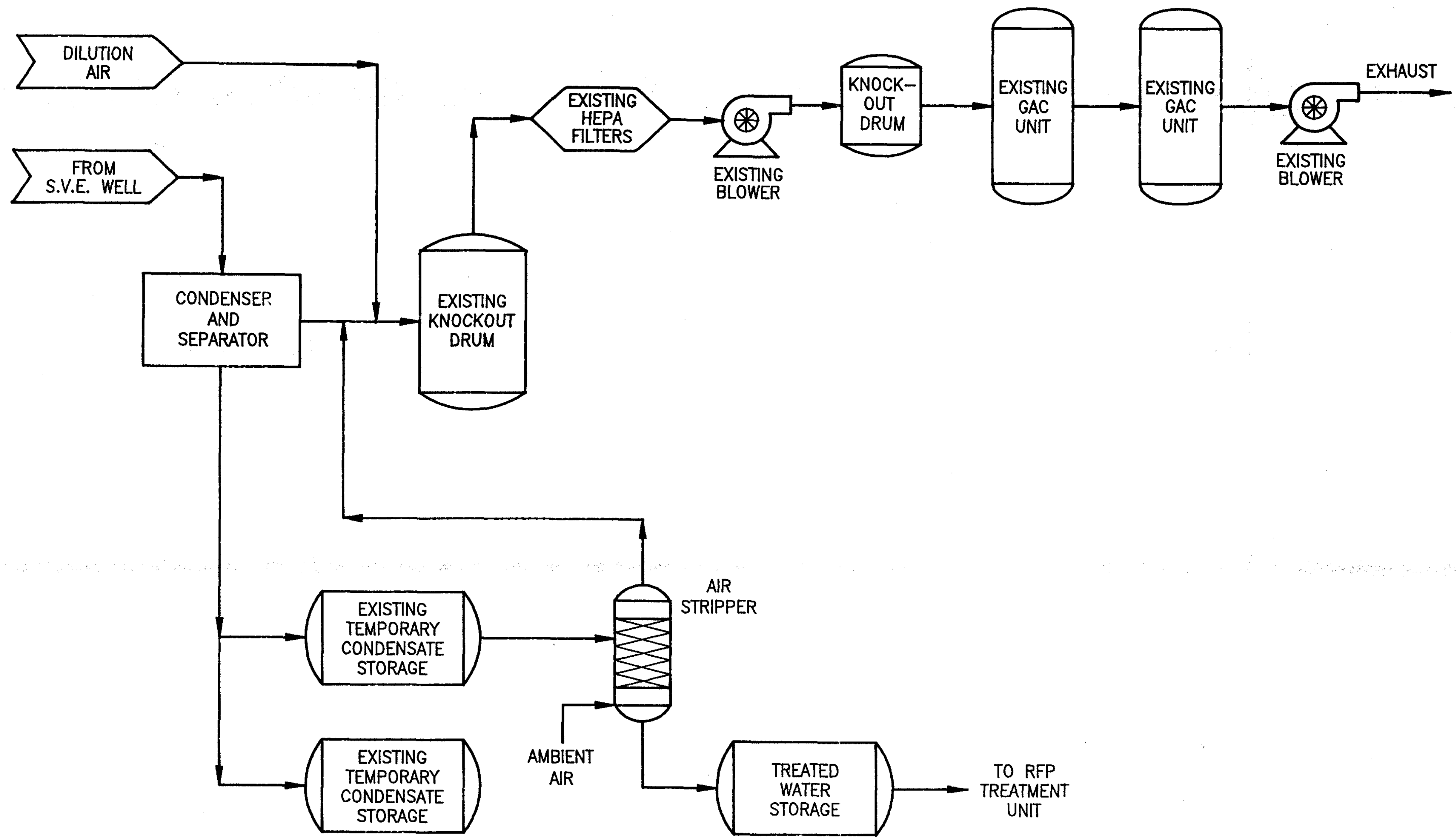
	Carbon Tetrachloride removal efficiency	PCE Removal Efficiency	TCE Removal Efficiency	Maximum VOC limit	Maximum single contaminant conc.	Maximum water vapor	Maximum inlet temperature	NO_x production rate	HCl production rate	Power requirements	Delivery time
Existing GAC with Offsite Regeneration	Greater than 99%	Greater than 99 percent	Greater than 99 percent	10,000 ppm	10,000 ppm			none	none		4-6 weeks
Membrane Separation	90-95%			No limit	No limit	No limit (water goes through membrane)		none	none	83 kW @ 300 scfm 167 kW @ 600 scfm	14 weeks
Adsorption/ Condensation	95-99%	99%	99%	5,300 ppm	5,300 ppm	100% Relative Humidity (RH)	120 °F	none	0	20.5 kW Ave 27.6 kW Max	8 weeks
Ozone-UV-GAC	95-98%	95-98%	95-98%	no limit	no limit	100% RH, and droplets are not a concern.		none	37.3 lb/hr	14 kW Ave	8 weeks
Condensation/ Refrigeration	Greater than 99.9%			900,000 ppm v		100% of flow		none	0	44 kW Ave	16 weeks
High Energy Corona	Greater than 99%			Testing up to 2,500 ppm v was successful. No higher tests.		100% RH at least. Higher contents unknown.		1 ppm	37.3 lb/hr	35-40 kW Ave	40 weeks
Thermal Oxidizer	Greater than 99%	Greater than 99%	Greater than 99%	5,000-6,000 ppm		80% RH Reheat before going to thermal unit. A larger water loading would require greater fuel and air consumption.	none	<5 ppm	37.3 lb/hr	4 kW Ave	16 weeks
Catalytic Oxidizer	Greater than 99%	Greater than 99%	Greater than 99%	5,000 ppm v with no dilution (no limit otherwise)	5,000 ppm v with no dilution (no limit otherwise)	100% RH, which would require supplemental fuel.	none	40 ppm @ 3% O_2	37.3 lb/hr	8 kW Ave	10 weeks
Flameless Thermal Oxidizer	Greater than 99%	Greater than 99%	Greater than 99%	No limit, except possible scrubber overload from C1	No limit, except possible scrubber overload from C1	80% RH, although a knockout drum for condensate will allow 100% RH.	none	<2 ppm	37.3 lb/hr	45 kW Ave 76 kW Max	14-20 weeks

TABLE 6.2-1
ALTERNATIVE COMPARISON
(Continued)

	Commercially Available?	No. of full scale units demonstrating DRE for CCl_4/PCE	By-products	Unit Operations (complexity)	Expandability	Skid Size
Existing GAC with Offsite Regeneration	Yes	many	Condensate Spent GAC	Condenser Air stripper GAC units	add more GAC columns	
Membrane Separation	Yes		Condensate Recovered VOCs	Condenser Air stripper Compressor Condenser Membrane Module GAC units		
Adsorption/Condensation	Yes	~ 10	Condensate HEPA filter Recovered VOCs	Condenser Adsorbtion beds Chiller/condenser Air stripper	Modular beds - add Refrig. units	7.5 ft x 12 ft.
Ozone-UV-GAC	Yes	≥ 3	Spent caustic HEPA filters	Cooler Photolytic reactor Aqua reactor/scrubber Ozone generator GAC units	Activated oxygen generator	10 ft. x 22 ft.
Condensation/Refrigeration	Yes		Condensate HEPA filters Recovered VOCs	Condenser Air stripper Refrig. condenser GAC		10 ft. X 30 ft.
High Energy Corona	No	0	Condensate HEPA filters Spent caustic	Condenser Air stripper HEC units Scrubber	Modular approach - add reactors - add power supply	6 ft. x 6 ft.

TABLE 6.2-1
ALTERNATIVE COMPARISON
(Concluded)

	Commercially Available?	No. of full scale units demonstrating DRE for CCl_4/PCE	By-products	Unit Operations (complexity)	Expandability	Skid Size
Thermal Oxidizer	Yes		Condensate HEPA filters Spent caustic	Condenser Air stripper Thermal oxidation Scrubber	Design in advance can then be upsized; Retrofit is much more expensive	6 ft. x 12 ft.
Catalytic Oxidizer	Yes	20 with CHCs, none with CCl_4 as primary constituent	Condensate HEPA filters Spent caustic	Condenser Air stripper Catalytic oxidation Scrubber	Oxidation chamber can be proportioned larger for more catalyst on larger frame. Design in Advance	4.2 ft x 8.75 ft.
Flameless Thermal Oxidizer	Yes		Condensate HEPA filters Spent caustic	Condenser Air stripper Flameless thermal ox. Scrubber	Design in advance	8 ft. x 30 ft.



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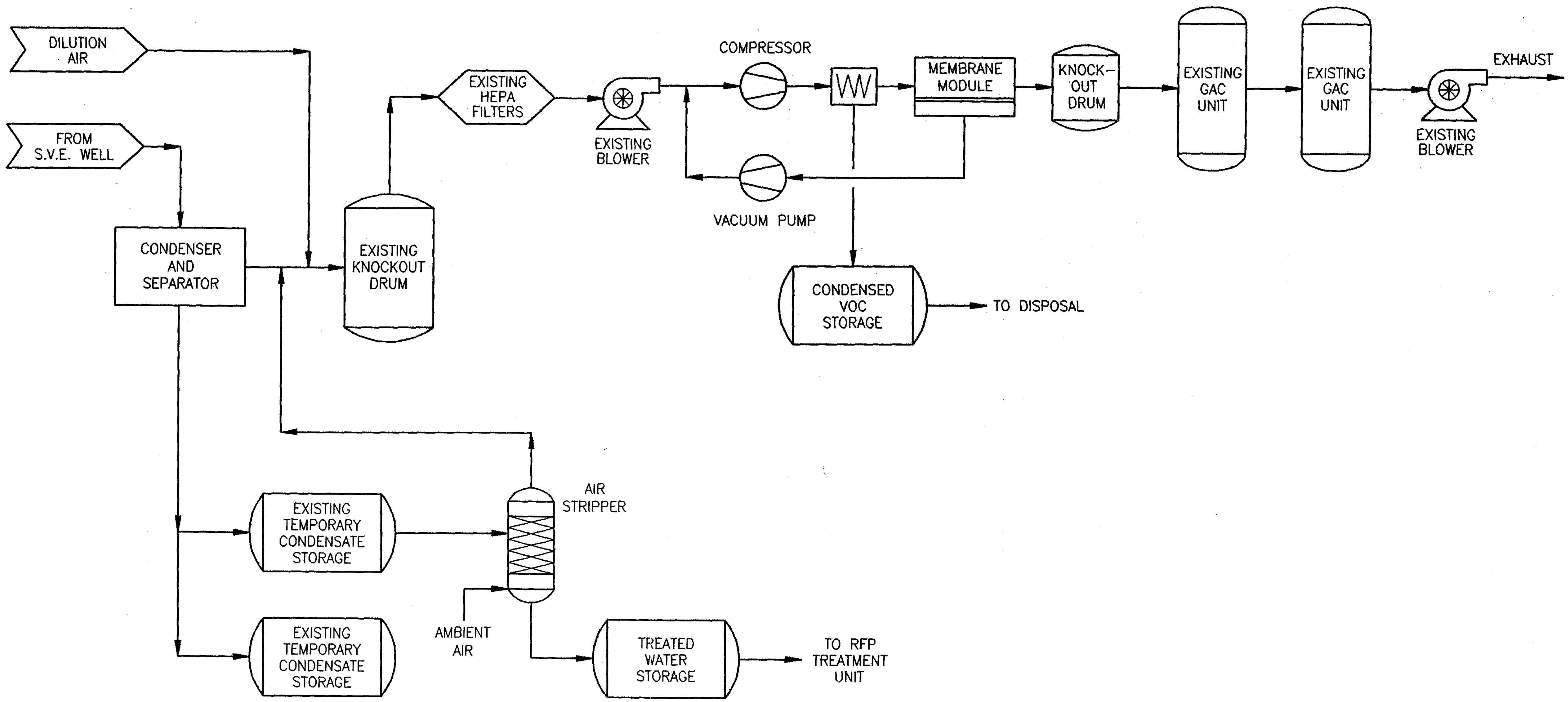
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMOANDUM NO. 2

GAC SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.2-1 MARCH 1994

4045024 1=1



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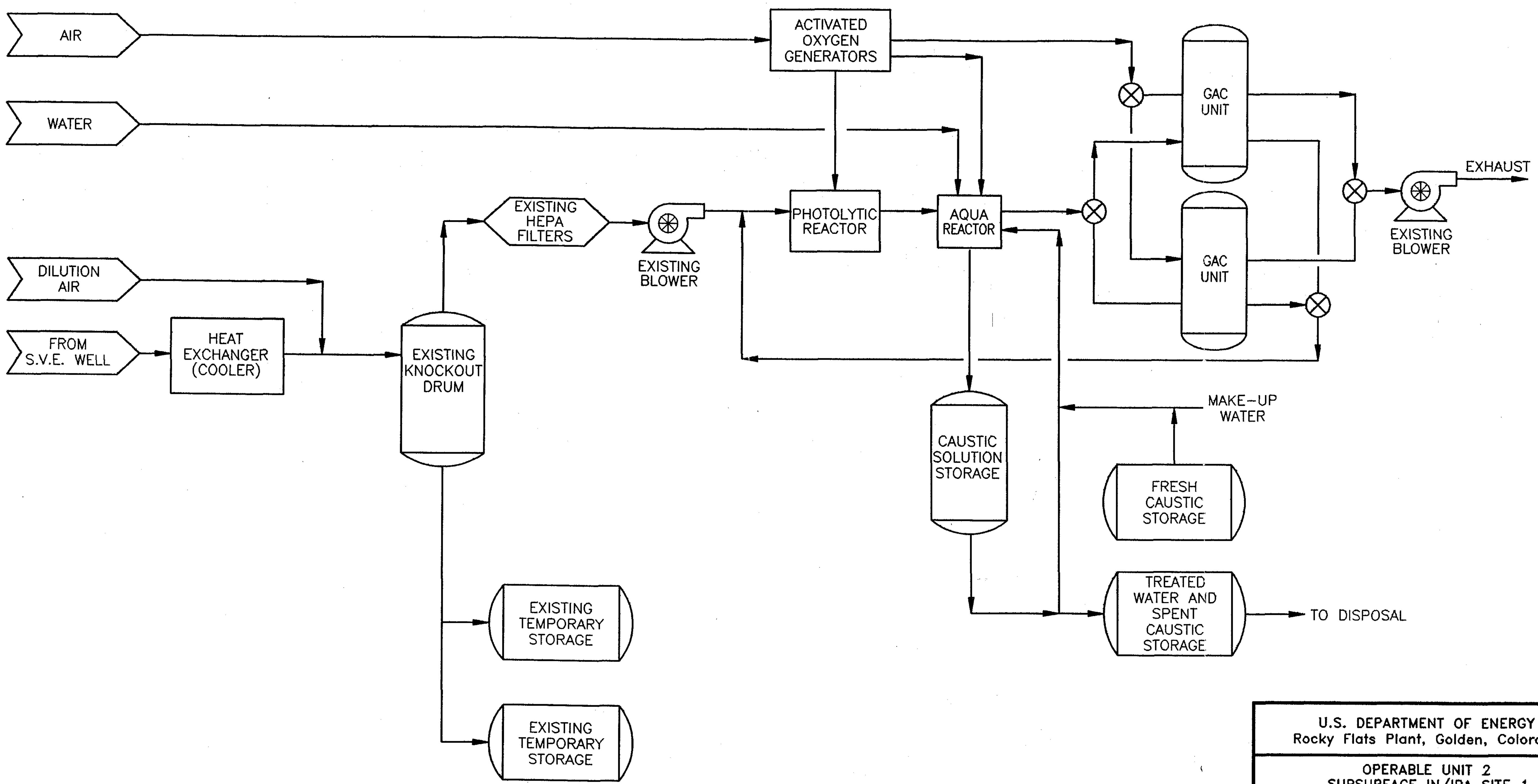
OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMOANDUM NO. 2

MEMBRANE SEPARATION SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.2-2

MARCH 1994

4045025 1=1



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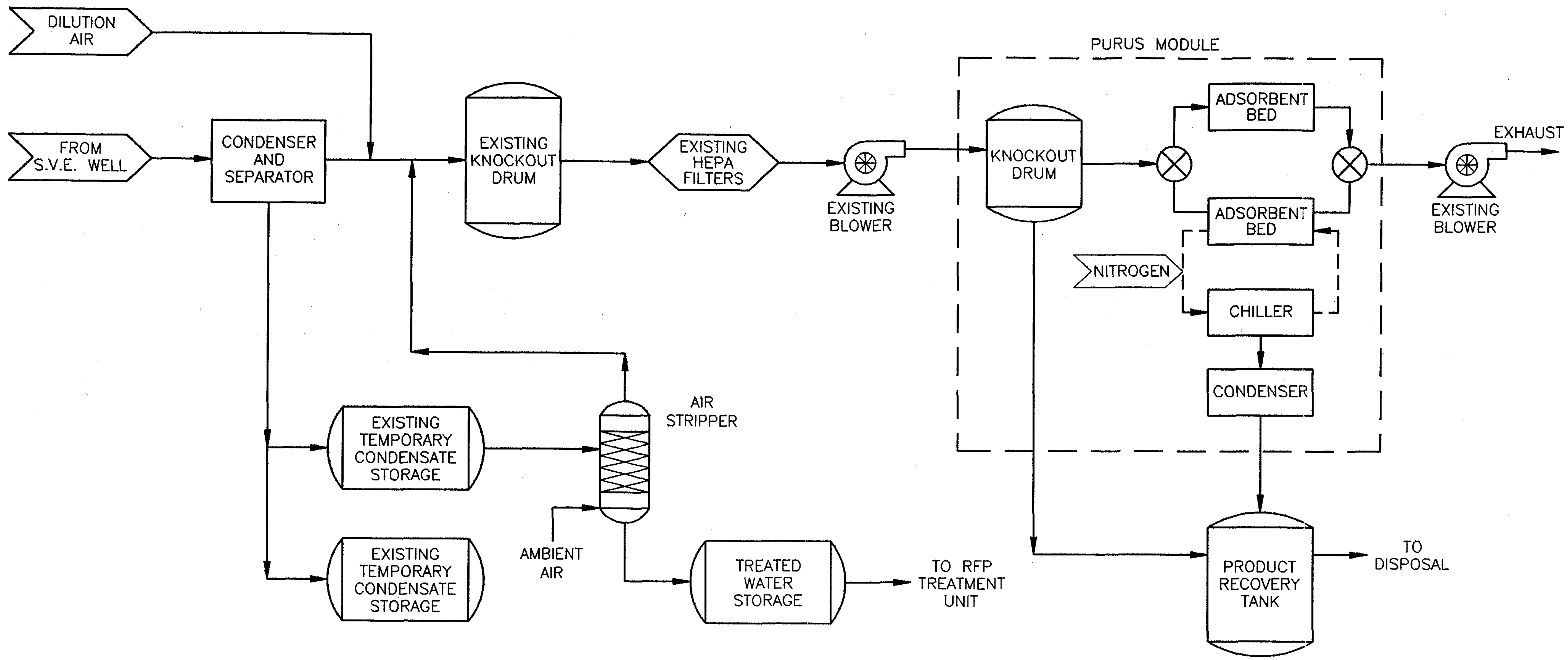
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMOANDUM NO. 2

OZONE-UV-GAC SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.2-3 MARCH 1994

4045014 1=1



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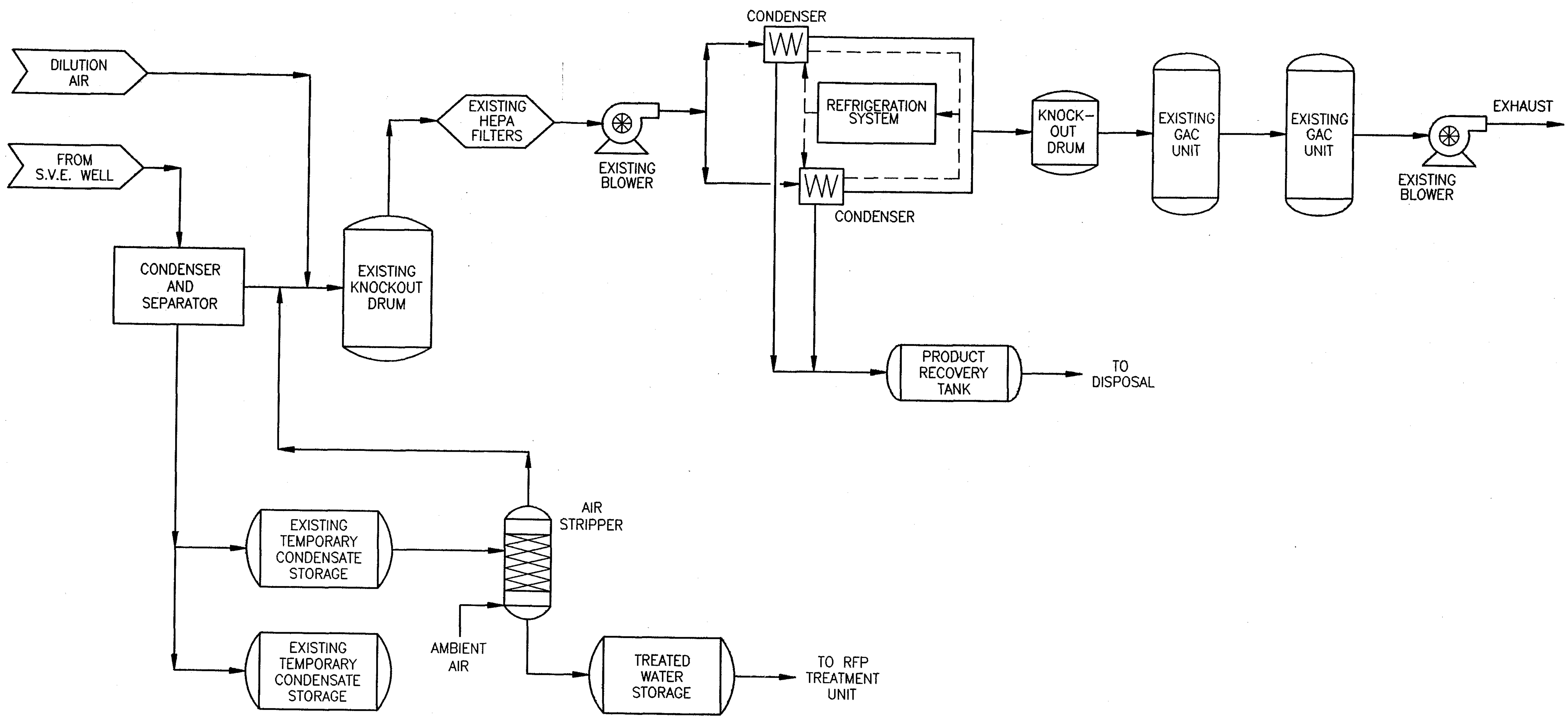
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMOANDUM NO. 2

ADSORPTION/CONDENSATION SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.2–4 MARCH 1994

4045010 1=1



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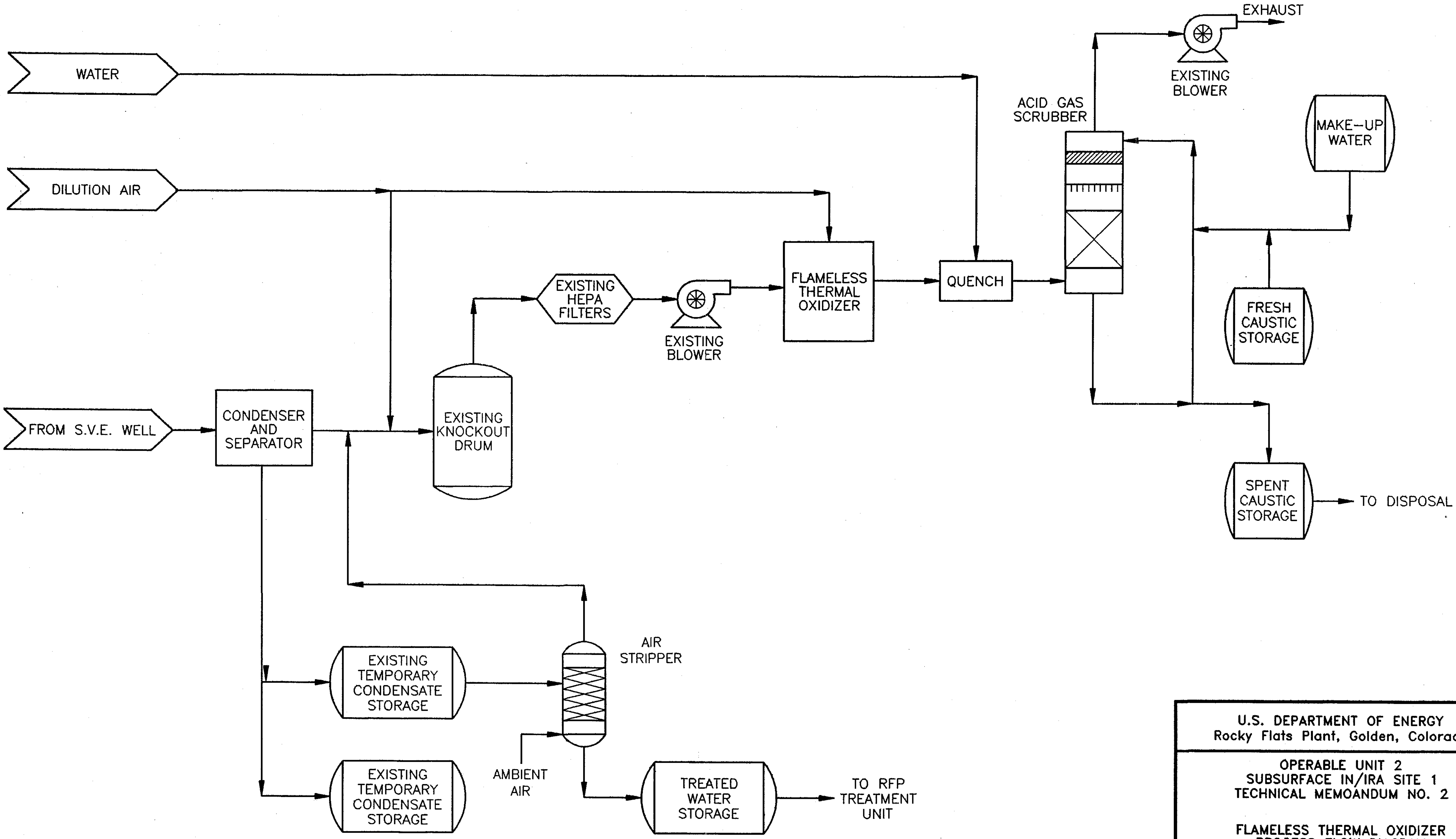
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMOANDUM NO. 2

CONDENSATION/REFRIGERATION SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.2-5 MARCH 1994



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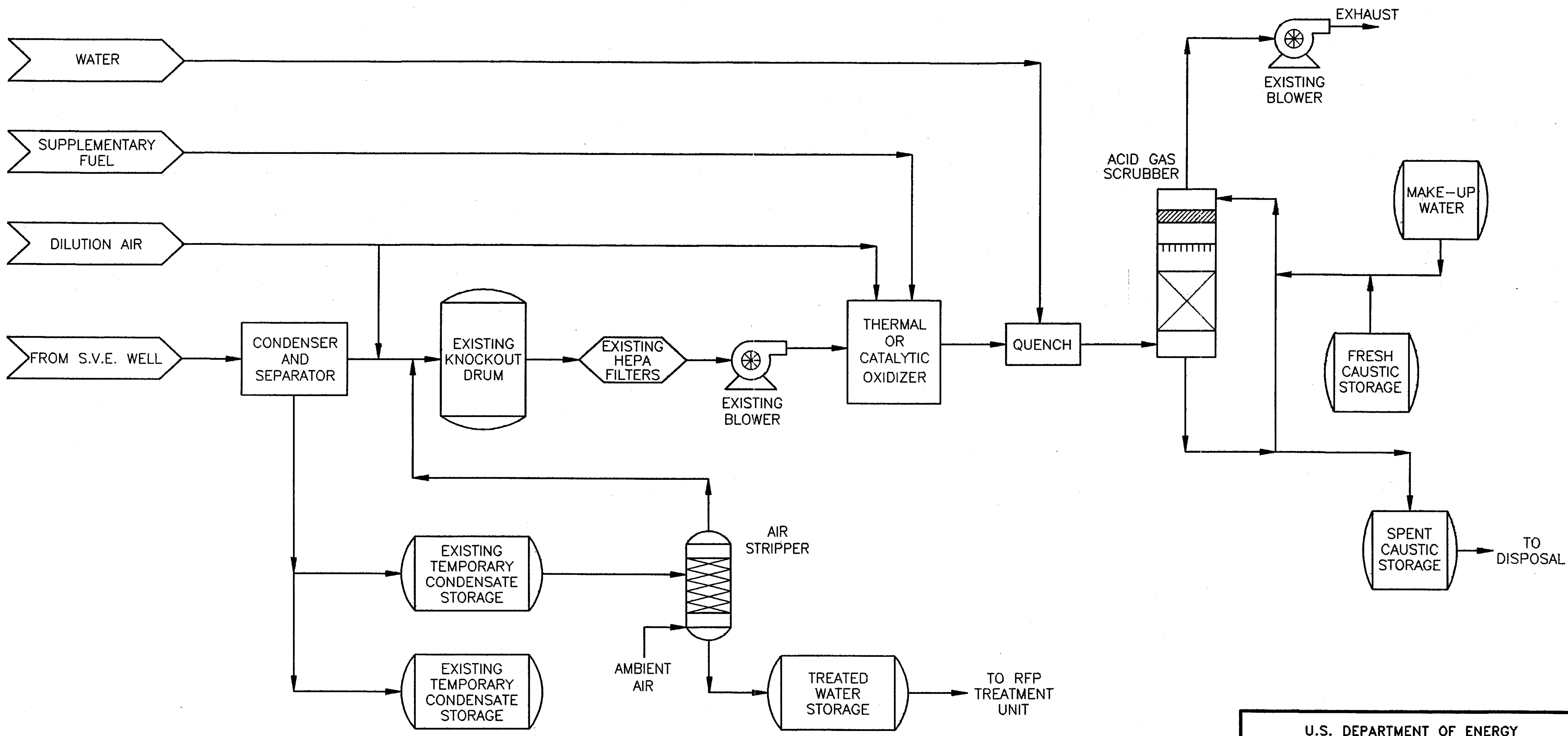
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMOANDUM NO. 2

FLAMELESS THERMAL OXIDIZER
PROCESS FLOW DIAGRAM

FIGURE 6.2-6 MARCH 1994

4045021 1=1



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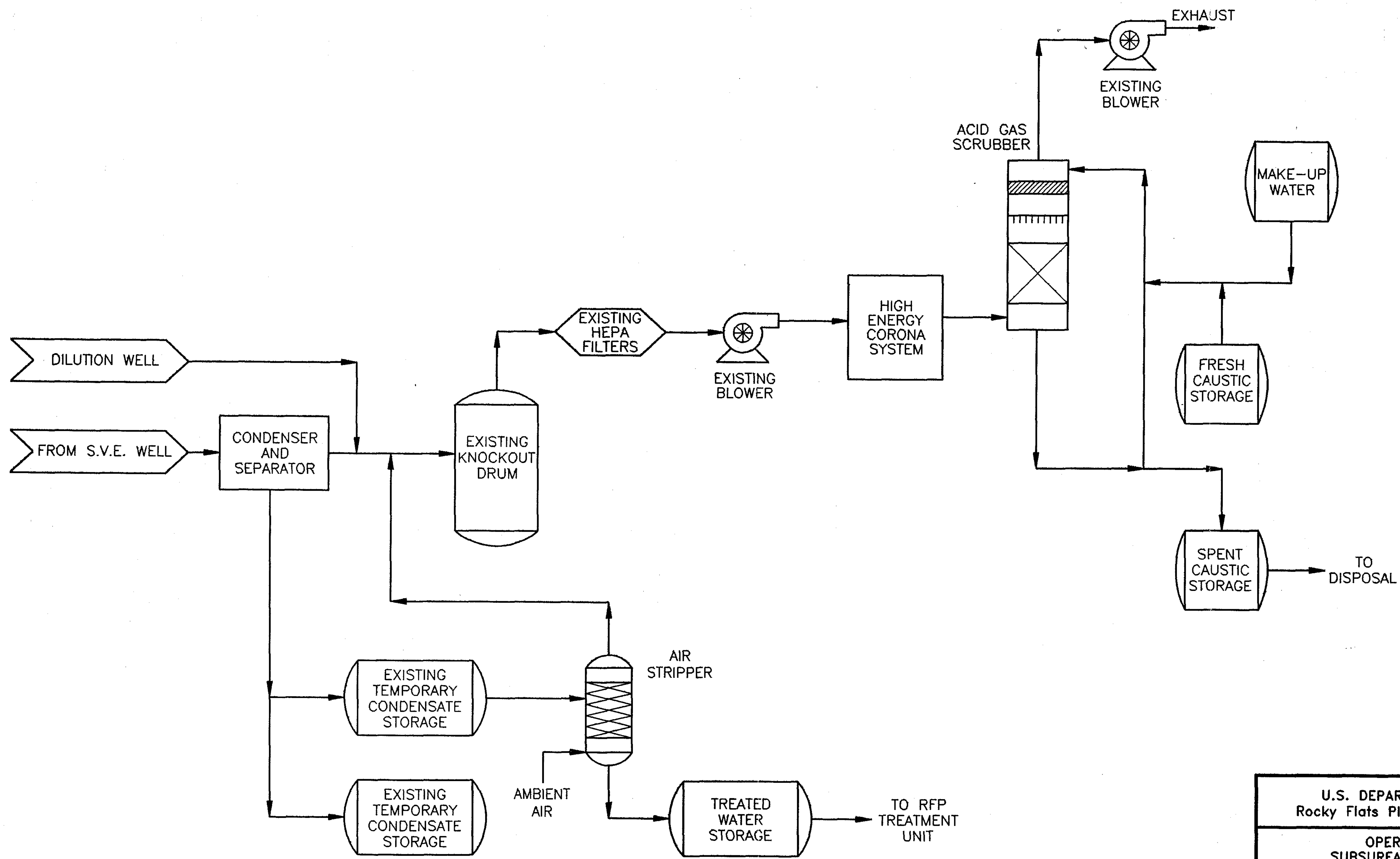
OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMOANDUM NO. 2

THERMAL/CATALYTIC OXIDIZER
PROCESS FLOW DIAGRAM

FIGURE 6.2–7 MARCH 1994

4045007 1=1



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Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMOANDUM NO. 2

HIGH ENERGY CORONA SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6.2-8 MARCH 1994

4045022 1=1